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Model PCX 15–1.5 MAT

Serial No. . . . . .

INSTRUCTION MANUAL

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THE POWER SUPPLIER™

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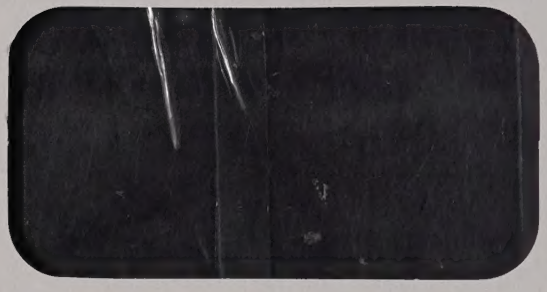

KEPCO

PCX

design group

PLUG-IN
MODULAR

POWER SUPPLY

Model PCX 15–1.5 MAT

Serial No. . . . . . .

INSTRUCTION MANUAL

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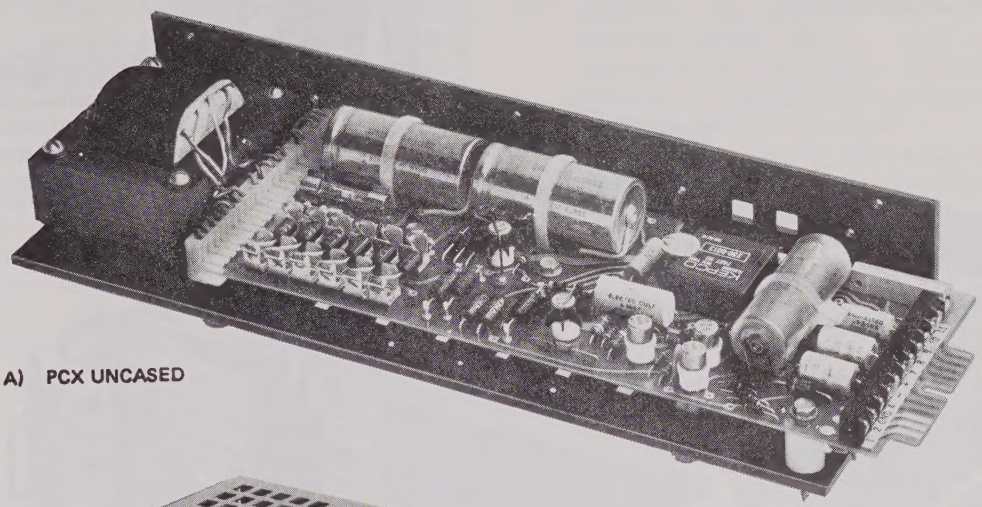
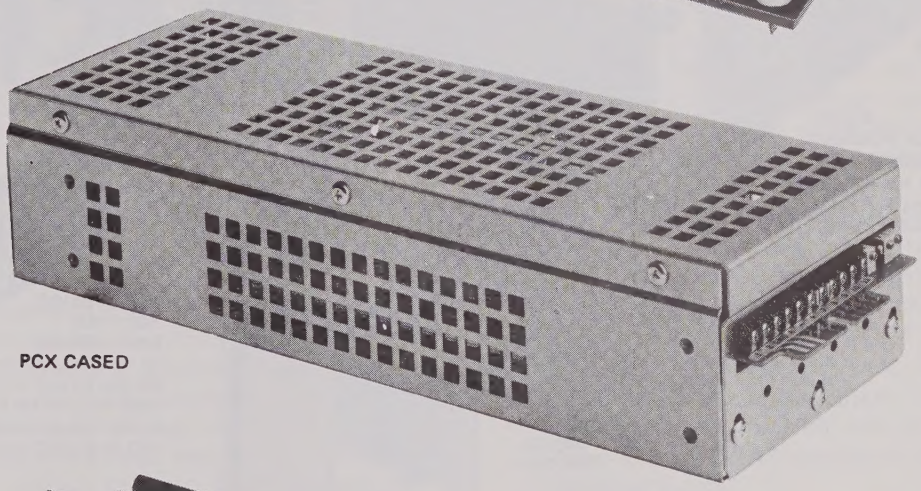
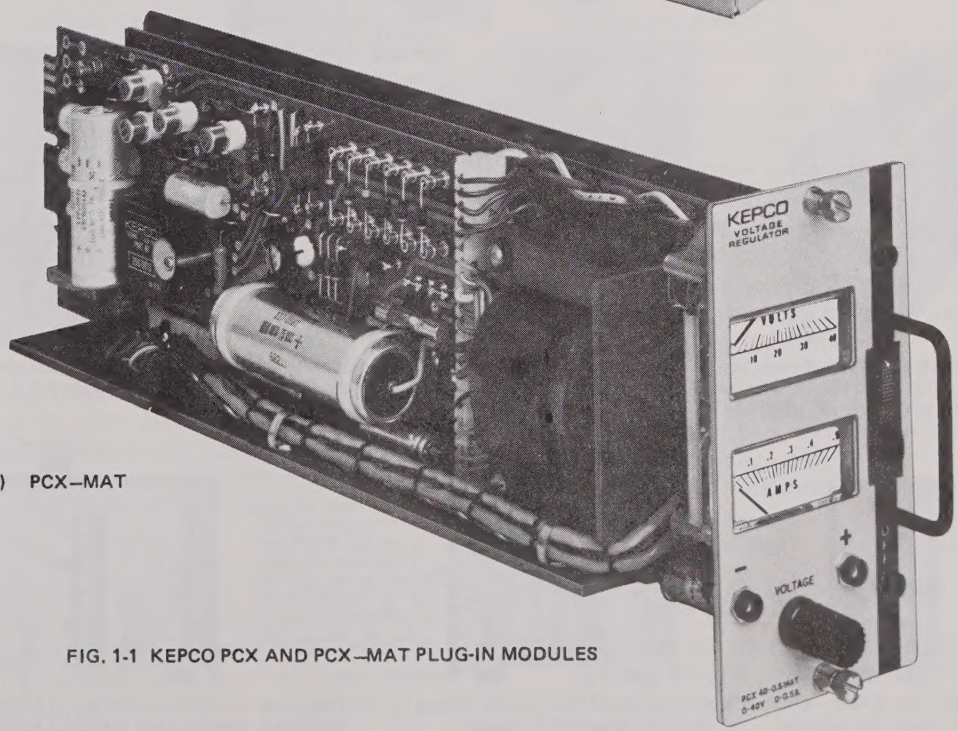


A) PCX UNCASED



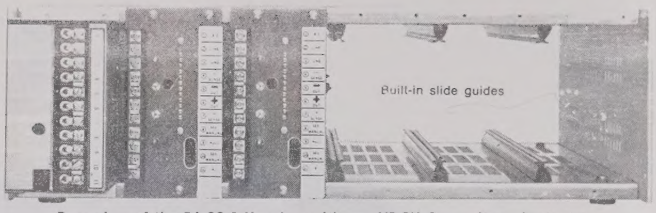
B) PCX CASED



C) PCX–MAT

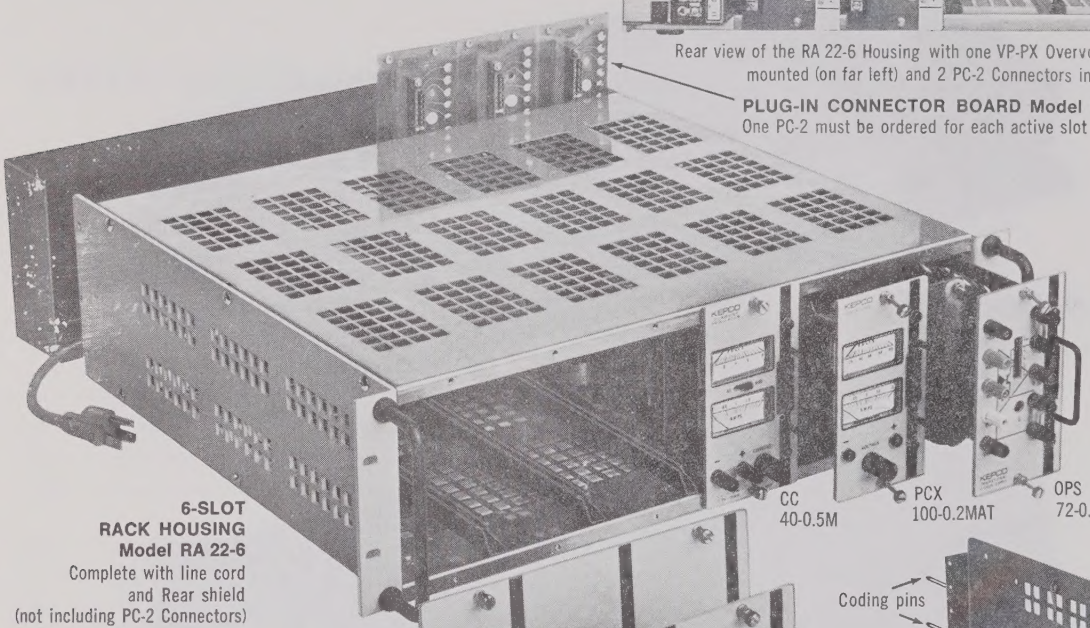
FIG. 1-1 KEPCO PCX AND PCX–MAT PLUG-IN MODULES

FIG. 1-2 KEPCO ENCLOSURES AND HARDWARE SYSTEMS FOR PLUG-IN MODULES

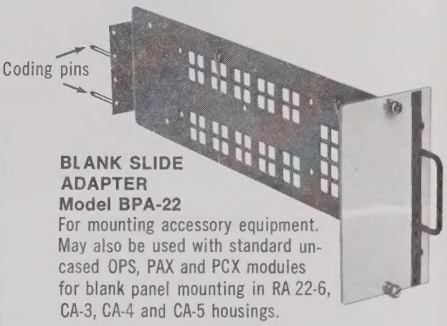


Rear view of the RA 22-6 Housing with one VP-PX Overvoltage Protector mounted (on far left) and 2 PC-2 Connectors installed

PLUG-IN CONNECTOR BOARD Model PC-2
One PC-2 must be ordered for each active slot in the RA 22-6.

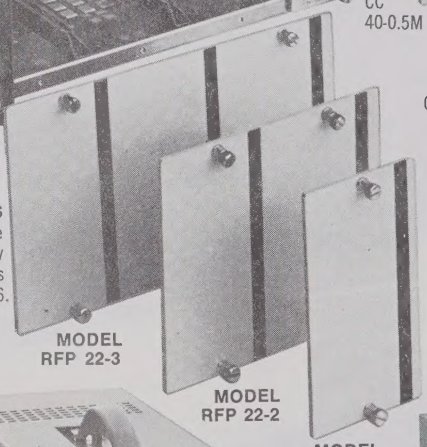


6-SLOT RACK HOUSING Model RA 22-6
Complete with line cord and Rear shield (not including PC-2 Connectors)



BLANK SLIDE ADAPTER Model BPA-22
For mounting accessory equipment. May also be used with standard uncased OPS, PAX and PCX modules for blank panel mounting in RA 22-6, CA-3, CA-4 and CA-5 housings.

FILLER PANELS
(supplied without slide assembly and handle), may be used to fill unused slots in CA-3, CA-4, CA-5 and RA 22-6.

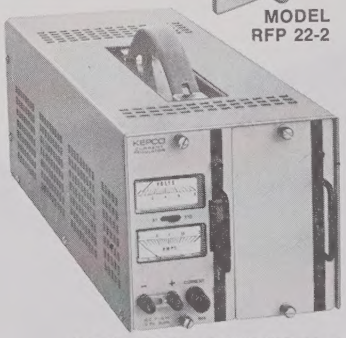


MODEL RFP 22-3

MODEL RFP 22-2

MODEL RFP 22-1

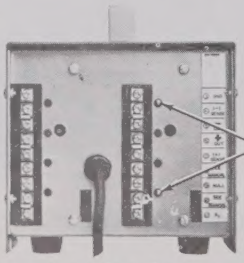
SINGLE UNIT HOUSING Model CA-3
Supplied complete with a built-in PC-2 connector. (shown with a PCX 100-0.2MAT plugged-in)



DOUBLE UNIT HOUSING Model CA-4
Supplied complete with a built-in dual PC-2 connector. (shown with a CC 40-0.5M and a BPA-22 plugged-in)

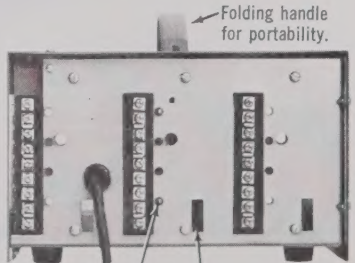
TRIPLE UNIT HOUSING Model CA-5
Supplied complete with a triple PC-2 connector.

Typical rear view of CA-3, showing access terminals and connector.



Typical rear view of CA-4, showing integral connector (Double PC-2) supplied.

All plug-in models and the BPA-22 are supplied with two coding pins that can be arranged in 6 different patterns to key the housing slots.



Typical rear view of CA-5, showing coding pins, connectors and line cord.

Slot provides access to internal adjustments in mounted supplies.

SECTION I – INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This manual contains instructions for the installation, operation and maintenance of the Kepco Series PCX and PCX–MAT Regulated DC Power Supplies.

1-3 GENERAL DESCRIPTION

1-4 The PCX and PCX–MAT Series represent a group of tightly regulated, low ripple power supplies of modular construction. While the PCX group is delivered as a power supply module without metering or controls, the PCX–MAT series is equipped with a functional front panel, containing full output metering, a ten-turn voltage control and AC input power switch and indicator. The two groups are identical with respect to their rear-terminal layout, electrical design and specifications. Interchange of PCX/PCX–MAT Models with similary rated models of the former Kepco Groups PBX/PBX–MAT is made possible by providing jumper connections on the PCX/PCX–MAT models. See Section V of this manual for details.

1-5 The PCX and PCX–MAT Series of power supplies feature a plug-in type, monolithic integrated circuit amplifier, specifically adapted to the critical needs of a power supply regulator. The amplifier provides a significant improvement over discrete component amplifiers especially in the DC power supply parameters. Other design features include a sharp current limit circuit, adjustable in the range from 10 to 105% of the rated output current, which protects the connected load and renders the PCX power supply completely short-circuit proof. Rear terminations on the PCX and PCX–MAT power supplies provide for AC input, DC output with "error sensing" and programming connections for remote output voltage control by resistance, voltage or current. In addition, PCX–MAT power supplies are equipped with additional front panel output terminals.

1-6 Optional accessories for the PCX models include a "Bridge Current Control" (Models with suffix "R") and a "Zero Control" (Models with suffix "E") which allow precision programming ratio adjustment. Models with suffix "T" have special reference sources and feature an all over temperature coefficient of 0.005% per degree centigrade.

1-7 The modular construction of the PCX and PCX–MAT power supplies permits installation in a variety of mounting accessories (Refer to FIG. 1-2 and paragraph 1-8) or the power supply module may be installed as an integral part of an existing installation.

1-8 ACCESSORIES

1-9 GENERAL. PCX and PCX–MAT modules are supplied without AC line cords. AC input connections (and DC output or programming connections) must therefore be made by means of one of the methods listed below:

a) Using any of the listed Kepco mounting accessories, all of which are equipped with AC line cords and mating adaptors for PCX and PCX–MAT power supply modules. The power supply output, sensing and programming terminals are made available at the rear-barrier strips of the chosen case or rack-cabinet.

b) If none of the Kepco mounting accessories are used, the printed circuit connector of the PCX or PCX–MAT power supply may be terminated with a mating jack, to which all necessary connections must be wired.

c) (PCX Models only.) All AC input, DC output and programming connections may be wired directly to the rear barrier strip. PCX models have a fixed control resistor across barrier strip terminals (7) and (8). This resistor is for preliminary checking purposes only and must be replaced by a high quality, wirewound control resistor as described in the operating section of this manual. (Refer to Section III.)

1-10 ENCLOSURES AND MOUNTING HARDWARE FOR KEPCO MODULAR SUPPLIES (OPTIONAL, not supplied with power supply. Refer to FIG. 1-2 for illustrations of the Kepco Hardware System.

a) MATING CONNECTOR, for uncased operation: KEPCO Model PC-1 or, METHODE Model CD-612-S-P7 (not shown).

b) SINGLE SLOT HOUSING, accepts single PCX module and provides all necessary rear terminations. KEPCO Model CA3. (AC Line Cord included).

c) DOUBLE SLOT HOUSING. KEPCO Model CA4, accepts two PCX modules or mixtures.* Rear terminations provided. (AC Line Cord included)

d) TRIPLE SLOT HOUSING, KEPCO Model CA5, accepts three PCX modules or mixture.* Rear terminations provided. (AC Line Cord included).

e) RACK CABINET, KEPCO Model RA 22–6, accepts six PCX modules or mixture.* Each mounted unit needs a plug-in adaptor (f). (AC Line Cord included)

*NOTE: Multiple slot housings will accept a mixture of Kepco modular units (OPS–BTA, PCX–MAT) as well as blank-panel inserts such as BPA and RFP.

f) PLUG-IN ADAPTOR, KEPCO Model PC2, required for rack-mounting each plug-in module.

g) FRONT PANEL, KEPCO Model BPA-22, blank panel with slide bracket for fitting accessory equipment or other Kepco modular unit without front panel attachements.

h) FILLER PANELS
   1) KEPCO Model RFP 22–1, to cover one (1) empty slot in rack cabinet (RA 22–6) or one of the multiple slot housings (CA4,CA5).
   2) KEPCO Model RFP 22–2, to cover two (2) emply slots.
   3) KEPCO Model RFP 22-3, to cover three (3) empty slots.

i) CASE, KEPCO MODEL CA-1, for PCX models only.

j) RACK ADAPTOR (for encased PCX models), KEPCO MODEL RA 12-1, for one unit (not illustrated).

k) RACK ADAPTOR (for encased PCX models), KEPCO MODEL RA 13-4, for four units (not illustrated).

l) RACK ADAPTOR (for encased PCX models), KEPCO MODEL RA 11-6, for six units (not illustrated).

1-11 SPECIFICATIONS, GENERAL

a) AC INPUT: 105 V to 125 V AC or 210 V to 250 V AC (selectable), 50 to 440 Hz, single phase. Input current: Refer to Table 1-1.

b) AMBIENT OPERATING TEMPERATURE: −20°C to +65°C.

c) STORAGE TEMPERATURE: −40°C to +85°C.

d) ISOLATION: 500 Volts maximum (DC or p–p) may be connected from chassis to either output terminal.

1-12 SPECIFICATIONS, PERFORMANCE

a) DC OUTPUT: Refer to Table 1-1.
AC INPUT: Refer to Table 1-1.

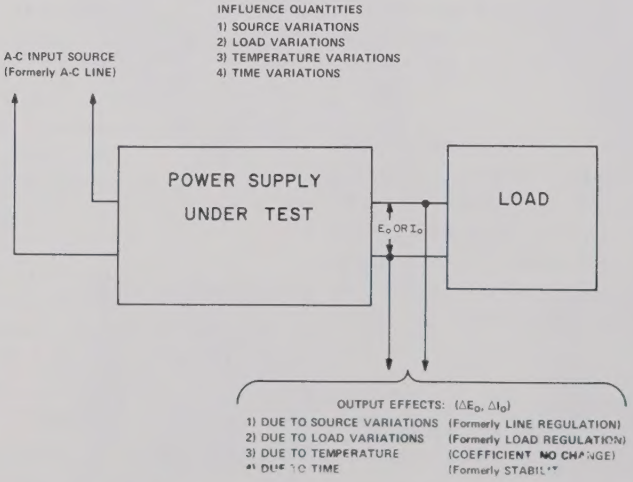
b) Output effect specifications for both operating modes are presented in Table 1-2.

1-13 SPECIFICATIONS, PHYSICAL

a) Refer to FIG. 1-3, "Mechanical Outline Drawing", for dimensions, materials used, and finish.

NOTE: With the introduction of the 1970 Catalog (B-703), Kepco has adopted new technical terms recommended by the International Electrotechnical Commission (IEC). These terms replace or supplement previously used expressions, mainly to avoid difficulties in translation and prevent erroneous interpretations at home and abroad.

As a beginning, Kepco will discontinue the use of the specifications entitled "Line Regulation" and "Load Regulation" because of the long standing (and misleading) connotation that a power supply regulates the line or the load. Instead, Kepco will follow the recommendation of the IEC and speak of the "Output Effects, caused by changes in the Influence Quantities." The "Output Effects" are specified as before, either as a percentage change referred to the maximum specified output voltage (E_o) or current (I_o) or as an absolute change (ΔE_o, ΔI_o) directly in millivolts or milliamperes or both. The "Influence Quantities" are the "Source Variations" (formerly a-c line variations), the changes in load, temperature or time as previously specified. The illustration below will clarify the use of the new terminology.



MODEL	DC OUTPUT RANGE		OUTPUT IMPEDANCE OHMS + MICROHENRIES			AC INPUT MAX. INPUT AMPS. at 125 V AC
	VOLTS	AMPS	DC to 100 Hz	100 Hz to 1 kHz	1 kHz to 100 kHz	
PCX 7–2	0–7	0–2	$0.2X10^{-3}$	0.02	0.1+1 μh	0.50
PCX 7–2MAT	0–7	0–2	$0.2X10^{-3}$	0.02	0.1+1 μh	0.50
PCX 15–1.5	0–15	0–1.5	$0.5X10^{-3}$	0.02	0.1+1 μh	0.65
PCX 15–1.5MAT	0–15	0–1.5	$0.5X10^{-3}$	0.02	0.1+1 μh	0.65
PCX 21–1	0–21	0–1	$1X10^{-3}$	0.02	0.1+1 μh	0.45
PCX 21–1MAT	0–21	0–1	$1X10^{-3}$	0.02	0.1+1 μh	0.45
PCX 40–0.5	0–40	0–0.5	$4X10^{-3}$	0.02	0.1+1 μh	0.40
PCX 40–0.5MAT	0–40	0–0.5	$4X10^{-3}$	0.02	0.1+1 μh	0.40
PCX 72–0.3	0–72	0–0.3	$12X10^{-3}$	0.02	0.1+1 μh	0.45
PCX 72–0.3MAT	0–72	0–0.3	$12X10^{-3}$	0.02	0.1+1 μh	0.45
PCX 100–0.2	0–100	0–0.2	$25X10^{-3}$	0.02	0.1+1 μh	0.45
PCX 100–0.2MAT	0–100	0–0.2	$25X10^{-3}$	0.02	0.1+1 μh	0.45

TABLE 1-1 OUTPUT/INPUT SPECIFICATIONS, PCX, PCX–MAT POWER SUPPLY MODULES

SPECIFICATION	OUTPUT EFFECTS VOLTAGE MODE	OUTPUT EFFECTS CURRENT MODE**	VOLTAGE AMPLIFIER OFFSETS****		VOLTAGE REFERENCE (Internal)****
			OFFSET VOLTAGE ΔE_{io}	OFFSET CURRENT ΔI_{io}	
OUTPUT RANGE:	0–100% E_o max.	1 mA–100% I_o max.			Fixed 6.2V±5%
SOURCE: 105–125/210–150V AC	<0.0005%	<0.005%	<10 μV	<2 nA	0.0001%
LOAD: No load – full load	<0.005% or 0.2 mV*	<0.01%	<200 μV	<5 nA	
TIME: 8-hours (drift)	<0.01% or 1 mV*	<0.02	<20 μV	<2 nA	0.005%
TEMPERATURE: Per °C	<0.01%***	<0.02***	<20 μV	<5 nA	0.005%
RIPPLE: (rms)	<0.1 mV	<0.02% of I_o max.			

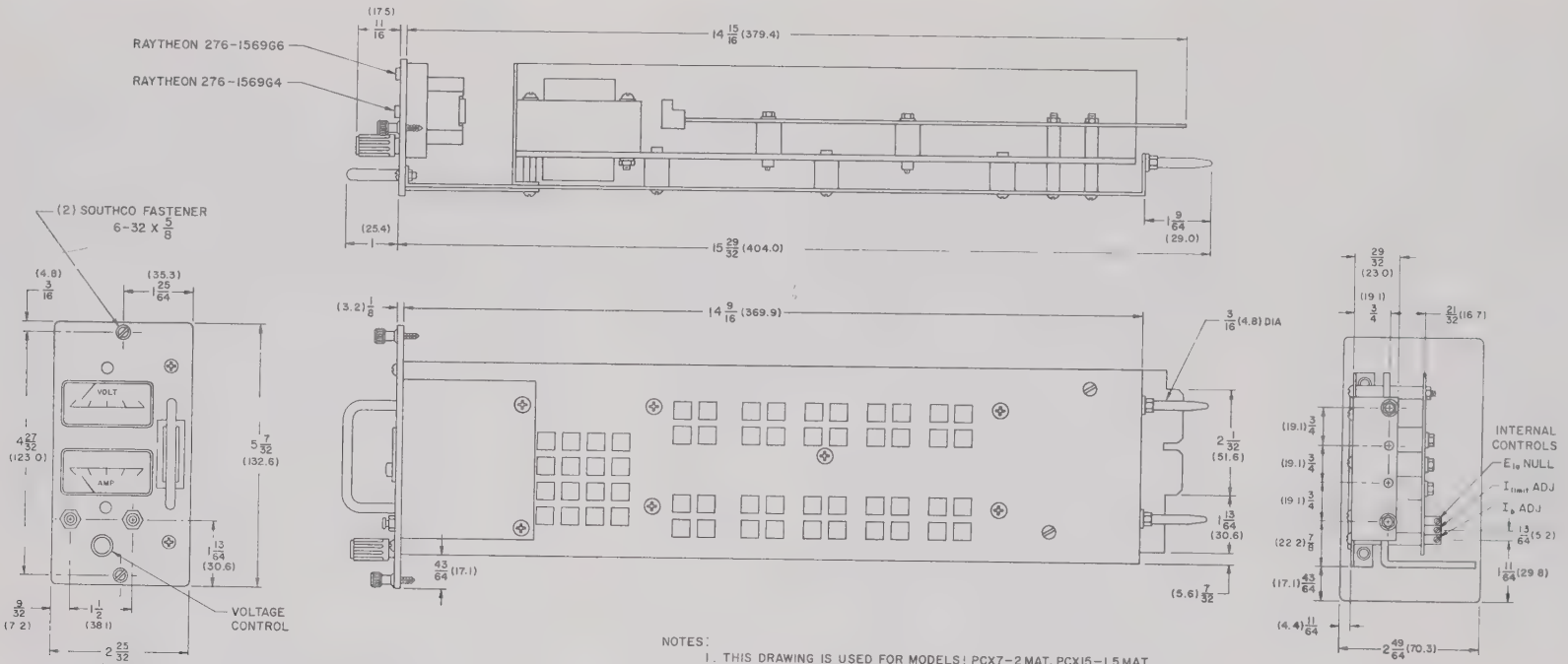
*Whichever is greater.

**"Rated Sample" is 1 volt DC across an external current sampling resistor having a temperature coefficient of 20 ppm (maximum). An external current control resistor with similar specifications must be used.

***PCX (PCX–MAT) Models with suffix "T" have a temperature coefficient of <0.005% of E_o max. per °C and <0.01% of I_o max. per °C in the respective operating modes.

****Offsets and the reference contribute to output effect ΔE_o, by the equation $\Delta E_o = \pm\Delta E_{ref}(R_f/R_i) \pm\Delta E_{io}(1 + R_f/R_i) \pm\Delta I_{io}(R_f)$ where R_f is the feedback resistor and R_i is the input resistor from the signal reference. Use the offsets to calculate output effects when external input/feedback elements are substituted for the internal reference and voltage control in programming applications.

TABLE 1-2 PERFORMANCE SPECIFICATIONS, PCX, PCX–MAT POWER SUPPLY MODULES



REAR CONNECTOR FUNCTIONS (P1)	
1) HOT	AC LINE
2) NEUTRAL	AC LINE
3) GROUND	AC LINE
4) (−) SENSING	
5) (−) OUTPUT	
6) (+) OUTPUT	
7) KEY−NO CONNECTION	
8) (+) SENSING	
9) R_{VC}	
10) NULL JUNCTION	
11) E_r	
12) R_r	

NOTES:
1. THIS DRAWING IS USED FOR MODELS: PCX7−2 MAT, PCX15−1.5 MAT, PCX21−1 MAT, PCX40−0.5 MAT, PCX72−0.3 MAT AND PCX100−0.2 MAT.
2. MAT'L: A) ADAPTOR BRACKET: 16 GAUGE COLD ROLLED STEEL;
   B) FRONT PANEL: 1/8 THICK ALUM.;
   C) CHASSIS: 1/8 THICK ALUM.
3. FINISH: A) ADAPTOR BRACKET: CADMIUM PLATE WITH A CHROMATE WASH,
   B) FRONT PANEL: LIGHT GRAY PER FEDERAL STD. 595 COLOR NO. 26440
   C) CHASSIS: BLUE ANODIZE.
4. REFER TO KEPCO CATALOG FOR DETAILED SPECIFICATIONS.
5. FUSE DATA:
   1) 115 VAC LINE: 0.8 A−SB; 230 VAC LINE: 0.4 A−SB } ALL MODELS.
   2) SLOW BLOW TYPE FUSE REQUIRED
6. PRINTED CIRCUIT BOARD CONNECTOR MATES WITH KEPCO MODEL PC−1 AND OTHER KEPCO ENCLOSURE TERMINATIONS, EQUIVALENT TO METHODE MODEL CD−612−S−P7
7. DIMENSIONS WITHIN PARENTHESES ARE IN MILLIMETERS.
8. TOLERANCES:
   A) BETWEEN MOUNTING HOLES: ± 1/64 INCH (±0.4 MILLIMETER)
   B) ALL FRONT PANEL DIMENSIONS: SEE MILL. STD 189
   C) ALL OTHER DIMENSIONS: ± 1/32 INCH (±0.8 MILLIMETER.

FIG. 1-3 MECHANICAL OUTLINE.

SECTION II – INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in paragraph 2-11 below. If any indication of damage is found, an immediate claim with the responsible transport service must be entered.

2-3 TERMINATIONS

a) FRONT PANEL: Refer to FIG. 2-1 (PCX–MAT only).

b) REAR: Refer to FIG. 2-2.

c) INTERNAL ADJUSTMENTS: Refer to Table 2-1.

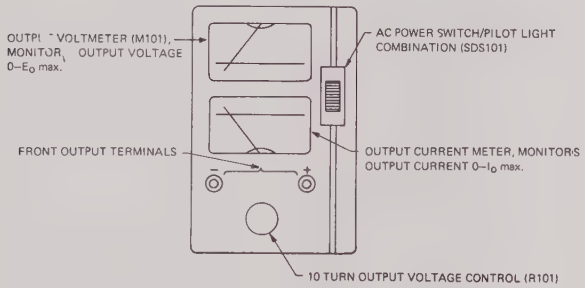

OUTPUT VOLTMETER (M101), MONITORS OUTPUT VOLTAGE 0–E_o max.
AC POWER SWITCH/PILOT LIGHT COMBINATION (SDS101)
FRONT OUTPUT TERMINALS
OUTPUT CURRENT METER, MONITORS OUTPUT CURRENT 0–I_o max.
10 TURN OUTPUT VOLTAGE CONTROL (R101)

FIG. 2-1 FRONT PANEL TERMINATIONS, PCX–MAT

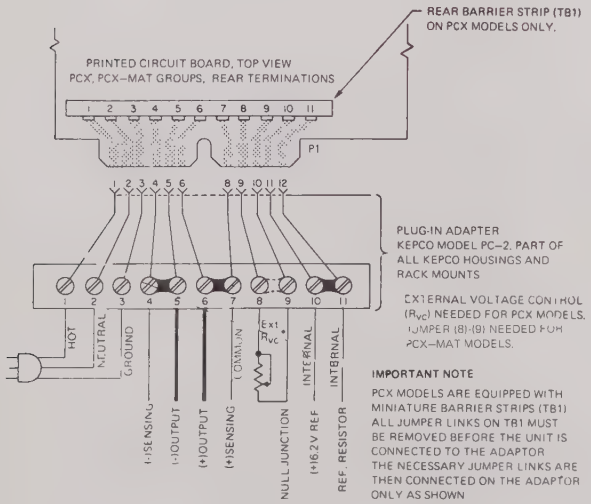

REAR BARRIER STRIP (TB1) ON PCX MODELS ONLY.
PRINTED CIRCUIT BOARD, TOP VIEW
PCX, PCX–MAT GROUPS, REAR TERMINATIONS
1 2 3 4 5 6 7 8 9 10 11
P1
1 2 3 4 5 6 8 9 10 11 12
PLUG-IN ADAPTER KEPCO MODEL PC–2, PART OF ALL KEPCO HOUSINGS AND RACK MOUNTS
EXTERNAL VOLTAGE CONTROL (R_{vc}) NEEDED FOR PCX MODELS. JUMPER (8)-(9) NEEDED FOR PCX–MAT MODELS.
HOT
NEUTRAL
GROUND
(–)SENSING
(–)OUTPUT
(+)OUTPUT
(+)SENSING
COMMON
Ext. 2V V_{vc}
INTERNAL
INTERNAL
NULL JUNCTION
(+)6.2 V REF
REF. RESISTOR
IMPORTANT NOTE
PCX MODELS ARE EQUIPPED WITH MINIATURE BARRIER STRIPS (TB1) ALL JUMPER LINKS ON TB1 MUST BE REMOVED BEFORE THE UNIT IS CONNECTED TO THE ADAPTOR THE NECESSARY JUMPER LINKS ARE THEN CONNECTED ON THE ADAPTOR ONLY AS SHOWN

FIG. 2-2 REAR TERMINATIONS, PCX AND PCX–MAT GROUPS

REFERENCE DESIGNATION	ADJUSTMENT	PURPOSE	ADJUSTMENT PROCEDURE
R19	I_o LIMIT	OVERLOAD CURRENT CONTROL	PAR. 5-11
R24**	E_{io} NULLING	ZERO OFFSET VOLTAGE	PAR. 3-12
R25*	R_{vc}	VOLTAGE CONTROL	PAR. 5-10
R27***	I_b ADJUST	CONTROL CURRENT ADJUSTMENT	PAR. 3-12

*MODELS WITH PREFIX 8000 ONLY
**MODELS WITH SUFFIX "E" ONLY
***MODELS WITH SUFFIX "R" ONLY

TABLE 2-1 INTERNAL CONTROLS

2-4 AC POWER REQUIREMENTS

2-5 PCX and PCX–MAT power supplies are normally delivered for operation on a single phase, 105 to 125 V AC source, 50 to 65 Hz. For operation on 210 to 225 V sources, the jumper connections on the main transformer (T201) must be changed as shown in FIG. 2-3

2-6 PROCEDURE:

a) Disconnect power supply from AC input source.

b) Remove bare wire jumpers between terminals (A) and (B) as well as (C) and (D).

c) Connect bare wire jumper between jumper terminals (B) and (C).

d) Replace 0.8 A fuse with 0.4 A (Slow Blow Type).

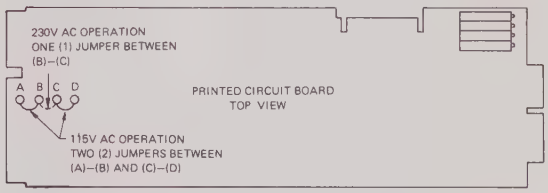

230V AC OPERATION
ONE (1) JUMPER BETWEEN (B)–(C)
A B C D
PRINTED CIRCUIT BOARD TOP VIEW
115V AC OPERATION
TWO (2) JUMPERS BETWEEN (A)–(B) AND (C)–(D)

FIG. 2-3 CONVERSION TO 230 V AC LINE OPERATION

2-7 SAFETY GROUNDING

2-8 For safety reasons it is imperative that the metal chassis be kept at ground potential. If a three-wire safety line cord and a properly grounded outlet are used, this is taken care of automatically. However, if only a two-wire line cord or an adaptor for a three-wire line cord is used, the pigtail wire of the adaptor, or the metal chassis of the power supply (via P1-3) must be returned to a good AC ground.

2-9 SIGNAL GROUNDING

2-10 The negative output terminal of the PCX/PCX–MAT power supply is connected to the chassis via a resistor/capacitor network (R17, C5). If the power supply is therefore properly safety grounded (see par. 2-7), a signal ground is provided automatically. If this internal signal ground is not desired, either output side may be signal grounded externally. The internal grounding network may be opened by removing either R17 or C5 from the printed circuit board. (Refer to FIG. 6-1.)

2-11 ISOLATION

2-12 The DC output terminals of the PCX and PCX–MAT Power Supplies are isolated from the AC power line and from the chassis. Since no DC connection to the chassis exists, either side of the supply may be grounded, or a maximum of 500 V (DC or AC peak-to-peak) can be connected between chassis and either output terminal.

2-13 PRELIMINARY CHECKOUT PROCEDURE

2-14 Before final installation, a simple functional check may be performed as described below:

a) PCX MODELS. Connect PCX to AC input power and connect a suitable DC voltmeter as shown in FIG. 2-4 below. The output voltage measured on the connected meter will be proportional to the resistance connected across terminals (8) and (9) of the rear barrier-strip on the power supply (TB1). Since a (nominal) 1 mA control current is used in PCX power supplies, the output voltage (E_O) will be approximately equal to the number of kilohms used times 1 mA.

The supplied carbon resistor connected across the barrier-strip terminals should not be used when making regulation or stability measurement. Instead it must be replaced by either a fixed or variable resistor having a temperature coefficient of not more than 20 parts per million. The value of the voltage control resistor to be selected depends upon the desired output voltage. For full output voltage control from zero to the maximum rated output voltage (E_O max.) the value of the variable control resistor (R_{VC}) should be:

$$R_{VC}\,(\text{K-ohms}) = E_O\ \text{max.}/1\ \text{mA}$$

For example, the resistor value for Model PCX 100-0.2 would be:

$$R_{VC}\,(\text{K-ohms}) = \frac{100\text{V}}{1\ \text{mA}} = 100\ \text{K ohm}$$

The selected value is connected across terminals TB1-8 and TB1-9. Full output control can now be exercised by varying R_{VC} from zero to full value. Remove AC input power. This concludes the preliminary checkout.

b) PCX–MAT MODELS. Connect to mating device (either one of the accessories described in paragraph 1-8) and to AC input power. Turn AC POWER SWITCH "on". (Refer to FIG. 2-2 for the location of the front panel controls.) AC POWER INDICATOR light (part of AC POWER SWITCH) should energize. Turn VOLTAGE CONTROL slowly clockwise and observe the increase of the output voltage on the panel meter (M101). The output should increase smoothly from zero to the maximum rated output voltage of the model under test. Shut AC POWER SWITCH "off." This concludes the preliminary checkout.

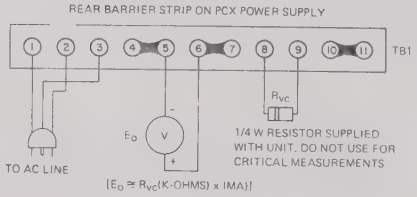


FIG. 2-4 OPERATION CHECK PCX

2-15 INSTALLATION

2-16 KEPCO modular, plug-in type power sources offer a wide variety of mounting possibilities (Refer to par. 1-8, "ACCESSORIES"). Whether single case, multiple housing or rack-installation is planned, installation consists simply in carefully sliding the module into one of the cabinets, making certain the printed circuit board connector of the unit has made positive contact with the mating plug in the housing.* Once the two holding screws on top and bottom of the front panel have been fastened, the unit is ready for operation.

2-17 COOLING

2-18 Modular units installed in single or multiple housings, or in rack cabinets must have sufficient air flow for effective convection cooling. Perforated side covers and tops must be kept clear from obstructions. In rack-installations, care must be taken that the temperature inside the rack does not exceed the specified ambient temperature. In extreme cases, the rack should be cooled by fans.

*NOTE: The distance from the outer edge of the printed circuit board connector to the rear of the front panel must be 15 inches ±1/32". If it is not, loosen holding screws (See FIG. 5-1) and re-align for exact distance.

3-1 STANDARD OPERATION, LOCAL CONTROL (Refer to FIG. 3-1)

3-2 With the PCX or PCX–MAT power supply terminated either with a simple mating plug (PC–1) or the plug-in adaptor PC–2 (part of all mounting accessories), the unit may be connected to the AC input power and is ready for operation.

3-3 The load should be connected as shown (on PCX–MAT models, the load may be connected to the front terminals). Error sensing, as described below (Refer to paragraph 3-5) is recommended to insure specified performance directly at the load. Standard jumper link connections for local control are shown in FIG. 3-1 below. All load connections and jumper links must be tight and secure for proper operation. If the indicated Plug-In Adaptor (PC-2) is not used, the jumper links must be provided on the mating connector to P1. In the case of PCX Models which are equipped with their own miniature barrier strip (TB1), the jumper links on TB1 must be removed, if an adaptor (PC2–part of all cases and rack mounts) is used.

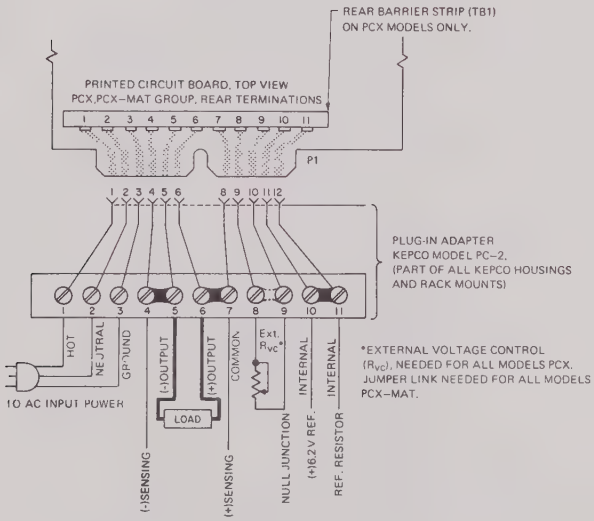


FIG. 3-1 REAR CONNECTIONS FOR STANDARD OPERATION

3-4 The connecting diagrams shown in the following paragraphs show ONE barrier strip only. This barrier strip represents the rear terminations of the PCX as well as that of the PCX–MAT group. The relationship between barrier strip terminals and pin numbers on P1 may be found by referring to FIG. 3-1. AC line connections (as shown in FIG. 3-1) have been omitted in order to simplify the presentation.

3-5 REMOTE ERROR SENSING

3-6 The error sensing leads are the input connections to the power supply's regulating system. They are terminated on terminals (4) and (7) of the adaptor plug barrier strip and normally connected to the output terminals (5) and (6) via removable links. With the links in place, specified regulation performance will be maintained at the rear output terminals of the power supply. Since the IR voltage drop across the load wires will degrade regulation at the load, the links connecting the sensing leads to the output terminals are now removed and the sensing terminals directly connected to the load.

3-7 PROCEDURE (Refer to FIG. 3-2)

a) Remove jumper links between terminals (4)-(5) and (6)-(7).

b) Use twisted wire, AWG#18 for the error sensing leads and twisted load wire as heavy as practicable, to reduce inductance and optimize transient recovery time. Observe polarities: The negative error sensing lead (4) must go to the negative load wire (5), the positive error sensing lead (7) to the positive load wire (6).

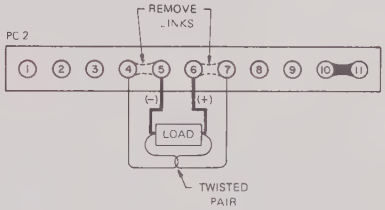


FIG. 3-2 LOAD CONNECTION WITH REMOTE ERROR SENSING

NOTE: An accidental open circuit in the remote sensing circuit will sharply degrade the regulating function and cause the output voltage and ripple to rise. In addition, an open load circuit, leaving the error sensing terminals connected to the load, may be damaging to the supply since the load current will attempt to flow through the sensing circuit.

When using remote error sensing, the power supply should be OFF when the load and sensing connections are being made. Be sure to connect the load before connecting the sensing wires and conversely, remove the sensing wires before removing the load leads.

3-8 INTRODUCTION TO REMOTE PROGRAMMING (Refer to FIG. 3-3)

3-9 A few general remarks may be in order to familiarize the user of this equipment with the terminology and basic equations pertaining to remote programming of the Kepco PCX and PCX–MAT Power Supplies. Electrically, the power supply consists of the unregulated DC source (E_u) the pass element (E_p), the DC error amplifier (A) and a comparison circuit which resembles a four-arm electrical bridge. (Refer to FIG. 3-3). The elements of the bridge are arranged to produce a virtual zero at the amplifier input when the bridge circuit is at balance ($V_{AA'}$=0). Any tendency for the output voltage to change in relation to the reference voltage (R_r) creates an error signal which, by means of negative feedback and the amplifier, tends to correct the output voltage towards restoration of bridge balance.

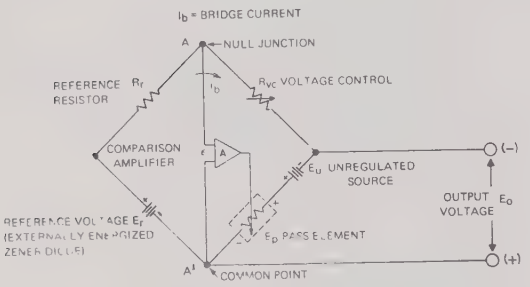


FIG. 3-3 KEPCO POWER SUPPLY AND COMPARISON BRIDGE CIRCUIT

3-10 EQUATIONS SHOWING THE OPERATION OF THE KEPCO BRIDGE

3-11 The following relationships govern the operation of the Kepco Bridge at balance, i.e., with $V_{AA'}$=0:

a) $$\frac{E_o}{E_r} = \frac{R_{vc}}{R_r} \quad (1)$$

$$\frac{E_r}{R_r} = I_b \quad (2)$$

$$E_o = I_b R_{vc} \quad (3)$$

Where: E_o = Output Voltage
E_r = Reference Voltage
R_r = Reference Resistance
R_{vc} = Control Resistance
I_b = Bridge Current

b) The ratio of the number of ohms control-resistance needed per volt output is termed the "CONTROL RATIO". It is nominally 1000 ohm/Volt in the PCX and PCX–MAT Power Supplies.

c) As can be seen from equation (1), the output voltage E_o can be controlled by varying any one of the three quantities. Rewriting equation (1) we have

$$E_o = \frac{E_r}{R_r} \times R_{vc}$$

The ratio $\frac{E_r}{R_r}$ constitutes the bridge current

I_b. $E_r/R_r = I_b$ (Eq. 2)

d) Therefore, we can write: $E_o = I_b R_{vc}$ (Eq.3). Making I_b a precision quantity (precision bridge current adjustment is described in Par. 3-12), establishes a precise programming ratio, so that the accuracy of E_o is solely dependent upon R_{vc}. This mode of operation is referred to as "RESISTANCE PROGRAMMING" and is covered in detail in Par. 3-23.

e) Rewriting Equation (1), $E_o = E_r \frac{R_{vc}}{R_r}$

we can make E_r the variable which controls E_o. This type of control is referred to as "VOLTAGE PROGRAMMING" and is covered in Par. 3-35.

f) Many other modes of control are of course possible; some of them are described in the following paragraphs. For a more extensive treatment and a detailed theoretical view of power supply applications, see the "Kepco Power Supply Handbook", available from your Kepco Representative or directly from the Kepco Applications Engineering Department.

NOTE: For all programming and adjustment components, use high quality, wire-wound, resistors with a T.C. of 20 p.p.m. or better.

3-12 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO

3-13 Referring to Equation (3): $E_o = I_b R_{vc}$, it is obvious that if I_b=1 mA, for each volt of output voltage E_o, 1000 ohms of Control Resistance R_{vc} is needed. The "Programming Ratio" of 1000 ohms per volt is therefore based on the bridge current, I_b.

In the PCX and PCX–MAT Power Supplies, this bridge current (I_b) is about 10% higher than 1 mA.

Again referring to $E_O = I_b R_{VC}$ (3), we see that if R_{VC} is made zero (shorted out), E_O should be zero. However, a small negative offset voltage will be found at the output under this condition.

Both "inaccuracies", the small offset voltage as well as the slightly larger bridge current, have been purposely designed into the PCX and PCX–MAT Power Supplies in order to simplify precision adjustment of the Programming Ratio.

Quite a number of methods are possible towards that end. The accuracy of the calibration is only limited by the precision of the test equipment in the laboratory. Since the availability of this equipment will vary from laboratory to laboratory, several procedures are described in the following paragraphs.

NOTE: The external control rheostats (R_T = "External I_b Control" and R_Z "External Zero Control") may be omitted in the following procedures and diagrams if the PCX or PCX–MAT power supply has these controls built-in. See appropiate notes in the "Equipment Required" paragraph of each procedure and in FIG.'s 3-4, 3-5 and 3-6.

3-14 METHOD #1 (ACCURACY DEPENDS ON MILLIAMMETER AND R_{VC})

3-15 EQUIPMENT REQUIRED:

a) Precision milliammeter, Weston Model 931 or equivalent. (M2)
b) Precision resistor 1 K ohm ±0.5% or better. (R_{VC})
c) Multimeter or other voltmeter for null indicator. (M1)
d) Single pole, single throw switch. (SW-1)
e) Rheostat (external "I_b" control) 0-1K (R_t) (May be omitted if Model has "R" suffix.)
f) Rheostat (External Zero Control) 0-200 Ω (R_Z). (May be omitted if Model has "E" suffix).

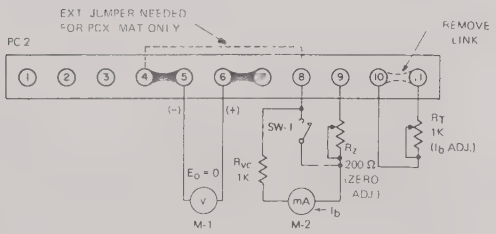


FIG. 3-4 PROGRAMMING RATIO CALIBRATION METHOD #1

3-16 PROCEDURE:

a) Connect calibration set-up as shown in FIG. 3-4.
b) Connect PCX or PCX–MAT Power Supply to AC input source. With SW-1 open, approximately 1 volt will be read at the output voltmeter, M-1.
c) Adjust R_t (Ext. I_b control) until milliammeter M-2 reads exactly 1 mA.
d) Disconnect power supply from the AC input source and mark zero reading of output voltmeter and reconnect to line.
e) Close SW-1 and adjust R_Z (External zeroing control) exactly to this established zero point.
f) Repeat (c),(d), and (e) until no further change is observed.

3-17 METHOD #2 (ACCURACY DEPENDS UPON CELL AND R_{VC})

3-18 EQUIPMENT REQUIRED:

a) Mercury cell, 1.35 V.
b) Precision resistor 1.35 K ±0.1%. (R_{VC})
c) Multimeter or other voltmeter as a null indicator. (M1)
d) DPDT switch. (SW-1)
e) Rheostat (external I_b adjustment) 0-1 K (R_t) (May be omitted if Model has "R" suffix).
f) Rheostat (External zero adjustment) 0-200 Ω (R_Z) (May be omitted if Model has "E" suffix).

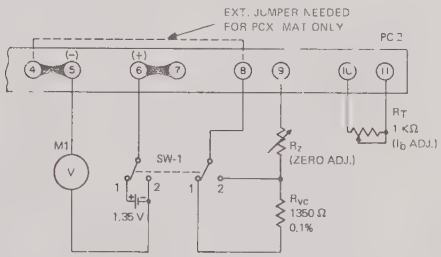


FIG. 3-5 PROGRAMMING RATIO CALIBRATION, METHOD #2

3-19 PROCEDURE

a) Connect calibration set-up as shown in FIG. 3-5
b) Connect power supply to AC input source. With SW-1 in Pos. 1, adjust R_t (external I_b control) to zero volts on the null meter.
c) Transfer SW-1 to Pos. 2. Adjust R_Z (External zero control) to zero volts on the null meter.
d) Return SW-1 to Pos. 1 and repeat (b) and (c) again until no further change is observed on the voltmeter.

VOLTMETER AND R_{VC})

3-21 EQUIPMENT REQUIRED:

a) Precision differential - or digital voltmeter. (M1)

b) A precision resistor (± 0.1%), equal to 1000 x E_O maximum (R_{VC}).

c) Single Pole, single throw switch (SW-1)

d) Rheostat (External I_b control) 0-1K (R_t) (May be omitted if Model has "R" suffix).

e) Rheostat (External Zero Control) 0-200 Ω (R_Z) May be omitted if Model has "E" suffix.

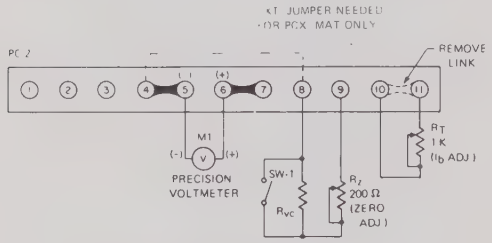


FIG. 3-6 PROGRAMMING RATIO CALIBRATION METHOD #3

3-22 PROCEDURE

a) Connect calibration set-up as shown in FIG. 3-6.

b) With SW-1 closed, adjust R_Z (External zero control) for zero volts on the precision voltmeter.

c) Open SW-1 and adjust R_t (External I_b control) exactly 1 volt per 1000 ohms.

d) Repeat (b) and (c) until no further change is observed on the voltmeter.

3-23 PROGRAMMING OUTPUT VOLTAGE WITH RESISTANCE

3-24 The output voltage of the PCX or PCX–MAT Power Supply can be varied by means of a control resistance connected between terminals (8) and (9) of the barrier strip. This resistance may be fixed, continuously adjustable, or stepped,* or it may be a combination of these.

The value of the output voltage is given by Equation (1):

$$E_O = R_{VC} \frac{E_r}{R_r}$$

Since $\frac{E_r}{R_r} = I_b$ (Eq.2), it follows that

$$E_O = I_b R_{VC} \text{ (Eq.3)}.$$

Referring to Equation (3), we see that since I_b is 1 mA in the PCX supplies (and can be precisely adjusted as shown in Par. 3-12), for every volt of output, 1000 ohms control resistance must be provided. This corresponds to a "Programming Ratio" of 1000 ohms per volt.

*NOTE: When fixed resistors are switched as the voltage control resistance, the switching device must have "Make before break" contacts in order transfer. While the steady-state current through R_{VC} is only 1 mA, it will rise to considerably higher peak values when large voltage steps are programmed. The programming resistors must absorb these peak currents which consist of energy stored in the output capacitor. Consequently, it is recommended that the dissipation rating of the programming resistors is increased to several times the steady state power dissipated in them.

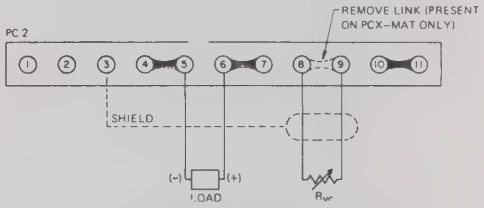


FIG. 3-7 CONNECTIONS FOR RESISTANCE PROGRAMMING

3-25 PROCEDURE (Refer to FIG. 3-7) PCX–MAT MODELS ONLY

a) Disconnect the internal voltage control on PCX–MAT Models by removing the jumper link between terminals (8)-(9). (PCX Models do not have a link between these terminals). There are two ways to connect the external R_{VC} to the PC2 barrier strip:

1) Connect R_{VC} between terminals (4) and (9).

2) Connect R_{VC} between terminals (8) and (9) and place a jumper on the PCB board as shown in FIG. 5-2. This method may be used for existing installations where Models PBX–MAT are replaced with PCX–MAT.

b) Determine value of programming resistor(s) for output voltage desired.

c) Using two-wire, shielded cable, connect the chosen resistors to terminals (8) and (9). Connect the shield to terminal (3).

d) The output voltage will vary from zero to (1 mA) x (R_{VC}), as R_{VC} is adjusted from zero to its maximum value.

3-26 CONSTANT CURRENT OPERATION

3-27 In the constant current operating mode, the voltage comparison bridge is interconnected with an external current sensing resistor, R_S and a current control, R_{CC}, (as shown in FIG. 3-8) to maintain a constant voltage drop across R_S. In this way, an adjustable constant load current is obtained. Characteristic of the constant current supply is the ability to change its output voltage automatically in order to maintain a constant current through a range of possible load resistances. The range of output voltage that the supply can deliver and simultaneously maintain constant current, is referred to as the "COMPLIANCE VOLTAGE".

3-28 The current sensing resistor R_S is chosen to develop a 1 volt drop at the maximum desired current. It is calculated by dividing this current into one volt. The value of R_S is not critical and can be the nearest standard resistance available. Several facts should be kept in mind however, when choosing R_S. A compromise must be made between a large and a small value. While a large value is desirable for good current regulation, it is less so in view of the power dissipated across it. It must be remembered that all the load current is flowing through R_S and the input to the regulator is connected across it. It is therefore vital that all extraneous changes across R_S, i.e. resistance change due to temperature, are kept to a minimum. A high quality, low T.C. (20 PPM) resistor, at least ten times the actual wattage needed, is therefore strongly recommended.

3-29 The current control resistor, (R_{CC}), is chosen on the basis of the control ratio of the Kepco comparison bridge, and V_S, the maximum voltage across R_S. If R_S was selected for 1 volt drop, then V_S = 1 Volt and $R_{CC} = V_S$ x (control ratio),

or R_{CC} = 1 volt x $(\frac{1000 \text{ ohm}}{1 \text{ volt}})$ = 1000 ohms.

A high quality, low T.C. (20 PPM) resistor is recommended for R_{CC}.

3-30 PROCEDURE (Refer to FIG. 3-8)

The actual set-up procedure for current regulation is perhaps best shown by a practical example. A PCX 72–0.3 MAT is to be set up for current regulated output from 30 mA to 300 mA.

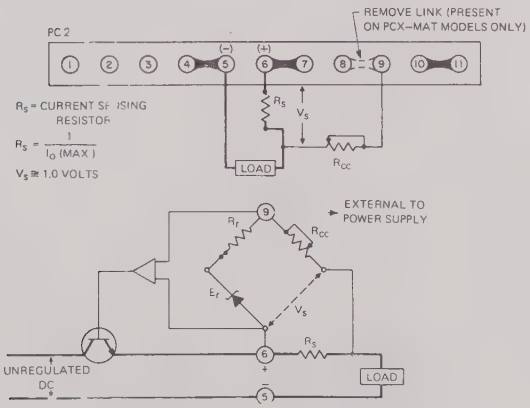


FIG. 3-8 CONNECTIONS FOR CONSTANT CURRENT OPERATION

a) R_S is chosen by: $R_S = \frac{1 \text{ volt}}{0.3 \text{ A}}$ = 3.33 ohm

$P_{diss} = V_S \times I_{max.}$ = 1 volt x (0.3 A) = 0.3 watts.

b) The control resistance R_{CC} is found by calculating its limits:

R_{CC} (max.) = V_S (max.) x control ratio =

1 V x $\frac{1000 \text{ ohms}}{\text{V}}$ = 1000 ohms.

R_{CC} (min.) = V_S (min.) x control ratio =

0.1 V x $\frac{1000 \text{ ohms}}{\text{V}}$ = 100 ohms.

As R_{CC} is therefore varied from 100 ohms to 1000 ohms, the regulated current will vary from 30 to 300 mA, and the compliance voltage from approximately zero to 71 volts.

c) Since, in the above example, the sensing voltage across R_S went below 1 volt at the low current output, the current regulation may not be sufficient for the purpose intended. (Specifications are based on 1 volt sample). To insure regulation figures within specifications, we must calculate R_S under minimum current conditions.

V_S min. = 1volt

$I_{min.}$ = 0.03A

$R_S = \frac{1 \text{ volt}}{0.03\text{A}}$ = 33.3 Ohms

The actual power dissipation of R_S is given by:

$P_{diss} = V_S$ (max.) x I_L (max.) = 10 V x 0.3 A = 3 watts.

(Three 100 ohm, 10 W, wire-wound resistors connected in parallel, will be satisfactory.)

R_{CC} will now be:

R_{CC} (max.) = V_S (max.) x control ratio = 10 V x 1000 ohm/V = 10 K ohm.

R_{CC} (min.) = V_S (min.) x control ratio = 1 V x 1000 ohm/V = 1 K ohm.

3-31 PROGRAMMING BY CONDUCTANCE

3-32 For special applications, the output voltage E_O can be adjusted by varying the bridge current. The relationship governing this type of programming is:

$E_O = E_r (R_{VC}) (G)$, or $E_O = \frac{E_r}{R_r + R_X} (R_{VC})$

Where: $G = \frac{1}{R_r + R_X}$ = programming conductance

E_O = output voltage
E_r = reference voltage
R_{VC} = control resistance
R_r = reference resistance
R_X = programming resistor

Since $\frac{E_r}{R_r} = I_b$ and $E_O = I_b R_{VC}$, the output voltage varies directly as I_b changes. Changing I_b with the help of an additional resistor in series with R_r results in an inversely proportional change of I_b, since now

$I_b = \frac{E_r}{R_r + R_X}$.

This method of output voltage adjustment is therefore referred to as conductance programming.

3-33 Conductance programming is inherently non-linear and a reciprocal function when analyzed in terms of resistance. It can however be very useful, especially over a limited range and for small changes in output voltage. Another distinctive advantage of this type of programming is the "built-in" safety feature. Should the programming circuit open accidently, the programming resistance becomes infinite, the conductance is zero, and consequently, the output voltage becomes zero.

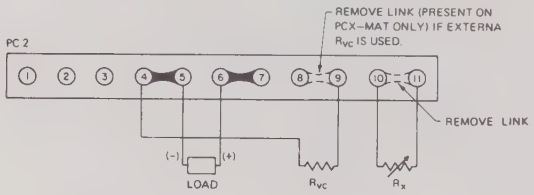


FIG. 3-9 CONNECTIONS FOR CONDUCTANCE PROGRAMMING

3-34 PROCEDURE

Example: E_o desired = 3 to 5 volts.

a) Select R_{VC} for maximum desired output voltage E_o.

$$R_{VC} = \frac{E_o}{I_b}, \quad R_{VC} = \frac{5\ V}{1\ mA} = 5\ K\ ohms$$

b) A change of E_o to 3 volts requires a bridge current change of:

$$\Delta I_b = \frac{\Delta E_o}{R_{VC}} = \frac{2\ volts}{5\ K\ ohms} = .4\ mA$$

c) Since $I_b, = \frac{E_r}{R_r} = 1\ mA,$

the additional resistance needed is:

$$I_b (R_r + R_x) = E_r,\ R_x = \frac{E_r}{I_b} - R_r \text{ or}$$

$$R_x = \frac{6\ volts}{0.6\ mA} - 6\ K = 4\ K\ ohms.$$

A 4K ohm, WW, low T.C. potentiometer will change the output voltage from 3 to 5 volts when varied from zero to 4K ohms.

NOTE: A word of caution may be in order in regard to the changing of the bridge current. The 1 mA value has been selected for greatest stability in the zener reference circuit. A large departure from this value is not advisable. If a ±50% change in I_b is not sufficient to achieve the desired voltage swing, an external reference supply can be used.

3-35 PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL VOLTAGE

3-36 The output voltage (E_o) of the PCX–MAT Power Supply can be varied by means of another external voltage source. This external programming voltage supplies the control current (I_b) formerly delivered by the internal reference voltage of the PCX supply. The output voltage (E_o) "follows" the programming source and maintains a value that remains in a constant proportion to it. The relationship governing this type of programming can be expressed by the equation:

$$E_o = E_i \frac{R_{VC}}{R_i}$$

Where: E_o = output voltage to be programmed.
E_i = programming voltage (input).
R_{VC} = voltage control resistance of the supply to be programmed. (R_{VC} can be either internally or externally connected).
R_i = external programming resistor (coupling resistor).

3-37 The values of the above quantities can be chosen to suit the particular application, although a few basic facts must be considered concerning their selection. E_o is, of course, limited by the maximum capability of the supply to be programmed. E_i can be any variable DC source having parameters at least as good as the desired E_o, and being able to deliver the necessary I_b. The resistors R_i and R_{VC} are selected by first determining I_b, desired bridge current.

Since I_b is supplied by E_i and also subtracts from the load current of the supply to be programmed, it should be kept as low as possible, but not under 100 μA.

3-38 Once I_b is selected and E_i as well as the desired output voltage E_o are known, R_{VC} and R_i are calculated by these simple relations:

$$R_{VC} = \frac{E_o}{I_b} \text{ (2)} \qquad \text{where } I_b = \frac{E_i}{R_i} \text{ (4) and}$$

$$E_o = \frac{E_i}{R_i} \times (R_{VC})$$

Stability, more than accuracy is the dominant critirium for selecting R_{VC} and R_i since part of the resistance can be made adjustable to compensate for tolerances and off-set voltages. Another important consideration in selecting control and programming resistors is to leave a wide safety margin when determining their wattage rating and to use only low temperature coefficient units.

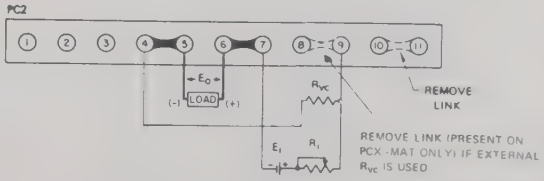


FIG. 3-10 CONNECTIONS FOR VOLTAGE PROGRAMMING

3-39 PROCEDURE (Refer to FIG. 3-10)

a) Connect components as shown in FIG. 3-10, disconnect link between terminals (10) and (11) on the barrier strip.

SECTION IV – THEORY OF OPERATION

4-1 GENERAL

4-2 This section contains the power supply circuit analysis. The operational theory, as far as it concerns remote programming, and the derivation of the transfer function were treated in Section III. The simplified diagram (FIG. 4-1) and the main schematic (FIG. 6-1) should be used to illustrate the contents of these paragraphs. References given in CAPITAL LETTERS refer to the nomenclature used in FIG. 4-1.

4-3 DETAILED CIRCUIT DESCRIPTION. (Refer to Main Schematic, FIG. 6-1)

4-4 For the purpose of convenient analysis, the circuitry of the PCX and PCX–MAT power supplies may be divided into several sections, which are subsequently described below:

a) AC INPUT CIRCUIT. AC input power is introduced through the rear printed circuit board (PCB) connector (P1), terminals (1) and (2). Terminal (3) is connected to the chassis and should always be returned to AC ground. Once the front panel slide switch/indicator is closed,* primary power is applied to the main transformer (T201) and the indicator lamp.* T201 has two primary windings, which are either connected in parallel (for 115 V AC service) or in series (for 230 V AC service). The fuse (F1) protects the primary winding of T201 from excessive current.

b) MAIN DC POWER SUPPLY. The main DC power is derived from a secondary winding on the main transformer (T201). Rectification and filtering is performed by a conventional bridge-rectifier circuit (CR4,5,6,7) and an electrolytic capacitor (C3). The main DC power supply delivers the rated output current and the operating voltage for the pass transistor.

c) PASS TRANSISTOR CIRCUITRY. The pass transistors (Q201,202) are connected in series with the plus (+) output terminal, the current sensing resistors (R16), the external load and the unregulated main DC supply. The output current flowing in the loop is kept constant, regardless of external changes in load resistance or AC input voltage, since the effective series resistance of the pass transistor is altered in reference to these changes. The base drive needed to produce this corrective action by the pass transistors, is supplied by the driver stage (Q2), which in turn is driven by either the Error Signal Amplifier (A_V), or the current limit amplifier (Q3,4).

d) ERROR SIGNAL AMPLIFIER (A_V). This device is a DC coupled, high–gain operational feedback amplifier, used in the inverting configuration. Its main function is to amplify the difference voltage (error-signal) existing between bridge terminals A-A' when an imbalance exists. The input of the amplifier is made available externally (via P1–10) for applying input signals (with respect to "common", P1–8) in remote programming applications. Error, as well as input signals are amplified by Av to a level suitable to pass the gate circuit and drive Q2.

*(SDS101, PCX–MAT MODELS ONLY)

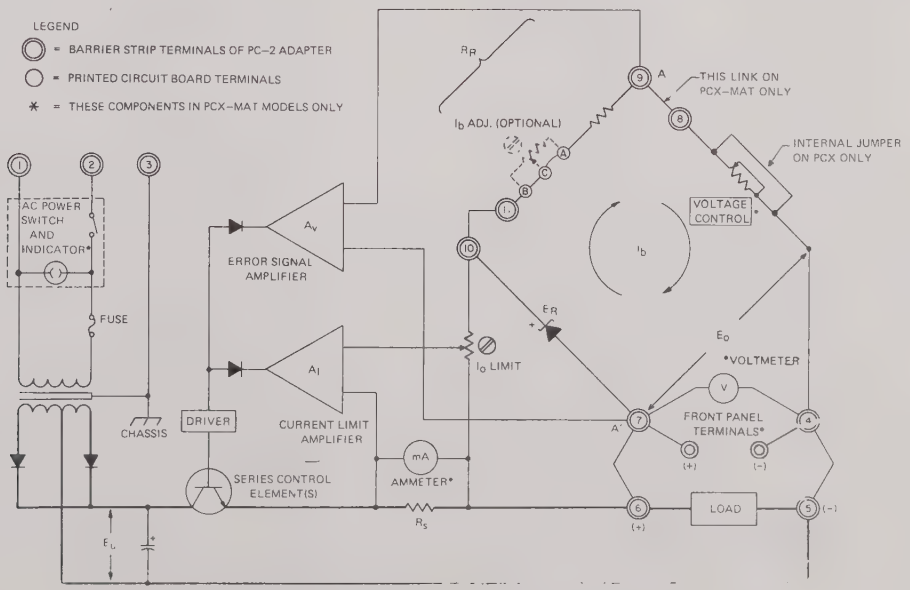


FIG. 4-1 PCX AND PCX–MAT POWER SUPPLY MODULE FEEDBACK REGULATOR SYSTEM (SIMPLIFIED SCHEMATIC)

e) The COMPARISON BRIDGE: This four-arm electrical bridge circuit is the regulating and controlling element in many KEPCO Power Supplies. In the PCX and PCX–MAT Model it consists of CR18 (E_r), R26 (R_r), the output voltage (E_o), and the voltage control resistance (R_{vc}). As shown in FIG. 4-1, a reference voltage (E_r) in series with the reference resistance (R_r) is continuously compared with the output voltage, (E_o) in series with the voltage control resistance, R_{vc}. At balance, a constant bridge current (I_b) is flowing through the bridge, keeping the error signal at bridge terminals (A) and (A') at approximately zero volts. Any deviation from the set output voltage will tend to change I_b in the sensing half of the bridge and thereby produce an error signal at the bridge terminals (A) and (A'). This error signal is then amplified and acts as a control signal for the series regulator transistor, changing the voltage drop across it in such a way as to compensate for the change in output voltage.

f) CURRENT LIMIT CIRCUITRY. The current limiting circuitry has the function to prevent output current flow beyond the maximum rated value. It performs this function by "cutting off" the pass transistor as soon as this value is reached. The differential inputs of the current limit amplifier (A_I = Q3,4) are connected to a current sensing resistor R_S (R16) and to a reference voltage. The voltage drop across R_S (due to load current flow) is continuously compared to the pre-set voltage at the "I_o Limit" control (R19). As long as the voltage developed across R_S is less than the pre-set voltage level at R19, the current amplifier will be biased to its inactive state and will have no effect on the output. Both, the current limit amplifier and error signal amplifier (A_V) are coupled through their respective gate diodes (CR16,17) to the driver transistor (Q2). The amplifier with the larger (negative) output will control the pass elements while the other amplifier is de-coupled. Since the voltage drop across the sensing resistor (R16) is proportional to the output current, and the "I_o Limit" may be set to a voltage exactly equal to that across R_S the current amplifier is inactive as long as the output current does not exceed the pre-set level. If the output current does increase however, the current amplifier will produce an output signal more negative than A_V, thereby taking control away from the voltage amplifier A_V and limiting the output current sharply in the process.

g) AUXILIARY SUPPLIES

1) AMPLIFIER POWER SUPPLY. This full wave, capacitor filtered source consists of a center-tapped winding on T201, silicon rectifier CR1, CR2 and the filter capacitor C1. A current regulator stage (Q1) followed by a string of zener diodes (CR11,CR12,CR13,CR14) provides the operating voltages for the amplifiers and is the source of the temperature compensated reference voltage (CR18). The positive reference voltage serves as the comparison source for the error signal amplifier (A_V) and produces the bridge current. The DC offset control (E_{io} Null) is also derived from the reference voltage. The offset control allows for precision zeroing of the initial amplifier offset and makes output voltage control to "true zero" possible (R24, on Models with suffix "E" only).

2) DRIVER COLLECTOR SUPPLY: A half-wave, capacitor filtered supply is derived from a winding on T201, rectified by silicon diode CR5 and filtered by C2. It delivers collector voltage to the driver transistor (Q2). R3 is a bleeder and CR15 is the coupling diode to the pass transistor.

3) I_{cbo} SUPPLY: The operating voltage for the I_{cbo} circuitry are derived from the main power supply. Q5 is biased by the voltage drop across the series diodes (CR9,10) in such a way as to draw a relatively constant current, thus providing a current sink for the I_{cbo} of the pass elements. This ensures positive cut-off, especially at high operating temperatures.

b) Component selection may be shown in the form of an example.

Example:

A PCX 40–0.5 MAT is to be programmed from zero to 30 V.

The programming source available is a variable 10 volt source, capable of delivering 5 mA. The bridge current is chosen to be 5 mA. We find R_{VC} and R_i by using equations (3) and (4).

(3) $R_{VC} = \frac{E_o}{I_b} = \frac{30\ V}{5\ mA} = 6\ K$

(4) $R_i = \frac{E_i}{I_b} = \frac{10\ V}{5\ mA} = 2\ K$

Power dissipated in
R_{VC} = 30 V x 0.005 A = .15 W (use 1 W).
Power dissipated in
R_i = 10 V x .005 A = .05 W (use .5 W).

3-40 SERIES OPERATION OF PCX–MAT MODULES

3-41 General. Kepco PCX–MAT Modules can be series connected for increased voltage output, provided the specified limits on voltage to chassis are not exceeded. When series-connected, the supplies should be protected by means of a semiconductor diode across the output terminals of each power supply, as shown in FIG. 3-11. The peak inverse rating of these diodes must be at least as large as the output voltage of the supply to which they are connected. The continuous current rating of the diodes should be at least as great as the largest short-circuit current of the interconnected supplies.

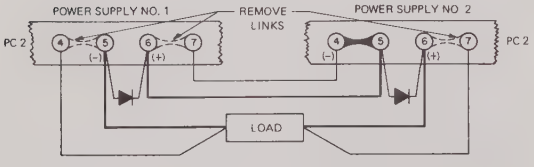


FIG. 3-11 SERIES CONNECTION OF PCX SUPPLIES

3-42 PROCEDURE

a) Connect load as shown in FIG. 3-11. Keep voltage drop in load wires as low as practical by using heavy gauge wire.

b) Connect protective diodes across respective output terminals.

c) Remove jumpers as shown and connect error sensing leads. These leads carry negligible current and can be approximately #18 gauge wire.

d) Turn supplies on and adjust voltage on either control as required.

3-43 PARALLEL OPERATION OF PCX–MAT MODULES

3-44 Two identical PCX–MAT power supplies may be operated in parallel for increased load-current output. Each supply is set to the desired output voltage with its respective Current Limiting Adjustment set to the maximum rated output current. After paralleling the two power supplies, one of the (supply #1) will inherently be at a slightly higher output voltage than the other (supply #2). Consequently, supply #1 will deliver all the load current up to the setting of its Current Limiting Adjustment. As the load is increased beyond this limit of supply #1, supply #2 takes over and delivers the additional current. The Current Limiting Adjustment of supply #1 can now be decreased, so that approximately equal current sharing is obtained. FIG. 3-12 shows in form of a diagram, how the two supplies operate in parallel, with their respective Current Limit Adjustments set to the maximum rated output current. It will be obvious from the diagram, that the areas of load regulation are within the output current bands of the individual supplies only. Therefore, load regulation cannot be measured from zero to twice the load current for example, but only within the individual load current bands. Error sensing as described in Par. 3-5, (from either supply) may be used if precise regulation at the load is required.

NOTE: When paralleling power supplies, care should be exercised to avoid turning the voltage control of only one supply close to zero. This precaution is necessary to prevent damaging currents in the voltage control resistor as its limiting resistance is lowered.

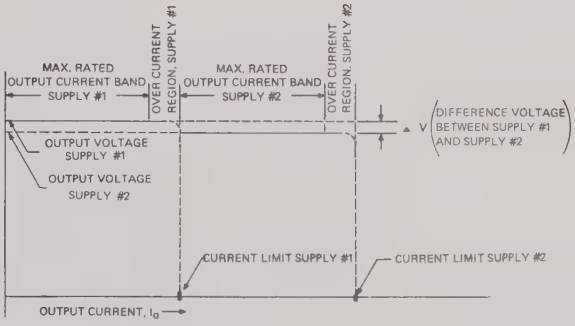

MAX. RATED OUTPUT CURRENT BAND SUPPLY #1
OVER CURRENT REGION, SUPPLY #1
MAX. RATED OUTPUT CURRENT BAND SUPPLY #2
OVER CURRENT REGION, SUPPLY #2
DIFFERENCE VOLTAGE BETWEEN SUPPLY #1 AND SUPPLY #2
OUTPUT VOLTAGE SUPPLY #1
OUTPUT VOLTAGE SUPPLY #2
CURRENT LIMIT SUPPLY #1
CURRENT LIMIT SUPPLY #2
OUTPUT CURRENT, I_o

FIG. 3-12 PARALLEL OPERATION, PCX–MAT POWER SUPPLIES

3-45 PROCEDURE (Refer to FIG. 3-13)

a) Connect units as shown in FIG. 3-13. Oper SW-1 and SW-2 and connect to AC input source.

b) Close SW-1 and adjust both units to the approximate output voltage desired.

approximate output voltage desired.

c) Close SW-2. Observe load current meters M1 and M2. Adjust Current Limit Adjust potentiometer R19 on the unit showing the higher current on its load current meter. Turn R19 counter clockwise until currents on M-1 and M-2 are approximately equal.

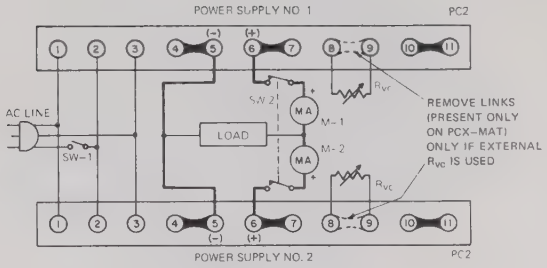


FIG. 3-13 PARALLEL CONNECTION OF PCX-MAT SUPPLIES

3-46 If single control of the parallel combination is desired, a master/slave connection may be substituted for the "automatic" parallel method shown in the previous paragraphs. If the two sensing resistors are selected such that $R_{S1} = R_{S2}$, each supply will deliver one half of the total load current. The sensing resistors should drop about 0.5 volt at the maximum operating current.

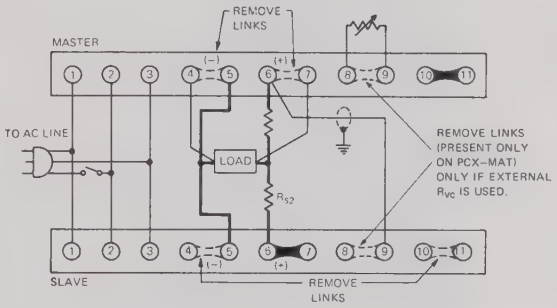


FIG. 3-14 MASTER/SLAVE PARALLEL CONNECTION

4-1 GENERAL

4-2 This section contains the power supply circuit analysis. The operational theory, as far as it concerns remote programming, and the derivation of the transfer function were treated in Section III. The simplified diagram (FIG. 4-1) and the main schematic (FIG. 6-1) should be used to illustrate the contents of these paragraphs. References given in CAPITAL LETTERS refer to the nomenclature used in FIG. 4-1.

4-3 DETAILED CIRCUIT DESCRIPTION. (Refer to Main Schematic, FIG. 6-1)

4-4 For the purpose of convenient analysis, the circuitry of the PCX and PCX–MAT power supplies may be divided into several sections, which are subsequently described below:

a) AC INPUT CIRCUIT. AC input power is introduced through the rear printed circuit board (PCB) connector (P1), terminals (1) and (2). Terminal (3) is connected to the chassis and should always be returned to AC ground. Once the front panel slide switch/indicator is closed,* primary power is applied to the main transformer (T201) and the indicator lamp.* T201 has two primary windings, which are either connected in parallel (for 115 V AC service) or in series (for 230 V AC service). The fuse (F1) protects the primary winding of T201 from excessive current.

b) MAIN DC POWER SUPPLY. The main DC power is derived from a secondary winding on the main transformer (T201). Rectification and filtering is performed by a conventional bridge-rectifier circuit (CR4,5,6,7) and an electrolytic capacitor (C3). The main DC power supply delivers the rated output current and the operating voltage for the pass transistor.

c) PASS TRANSISTOR CIRCUITRY. The pass transistors (Q201,202) are connected in series with the plus (+) output terminal, the current sensing resistors (R16), the external load and the unregulated main DC supply. The output current flowing in the loop is kept constant, regardless of external changes in load resistance or AC input voltage, since the effective series resistance of the pass transistor is altered in reference to these changes. The base drive needed to produce this corrective action by the pass transistors, is supplied by the driver stage (Q2), which in turn is driven by either the Error Signal Amplifier (A_V), or the current limit amplifier (Q3,4).

d) ERROR SIGNAL AMPLIFIER (A_V). This device is a DC coupled, high–gain operational feedback amplifier, used in the inverting configuration. Its main function is to amplify the difference voltage (error-signal) existing between bridge terminals A-A' when an imbalance exists. The input of the amplifier is made available externally (via P1–10) for applying input signals (with respect to "common", P1–8) in remote programming applications. Error, as well as input signals are amplified by Av to a level suitable to pass the gate circuit and drive Q2.

*(SDS101, PCX–MAT MODELS ONLY)

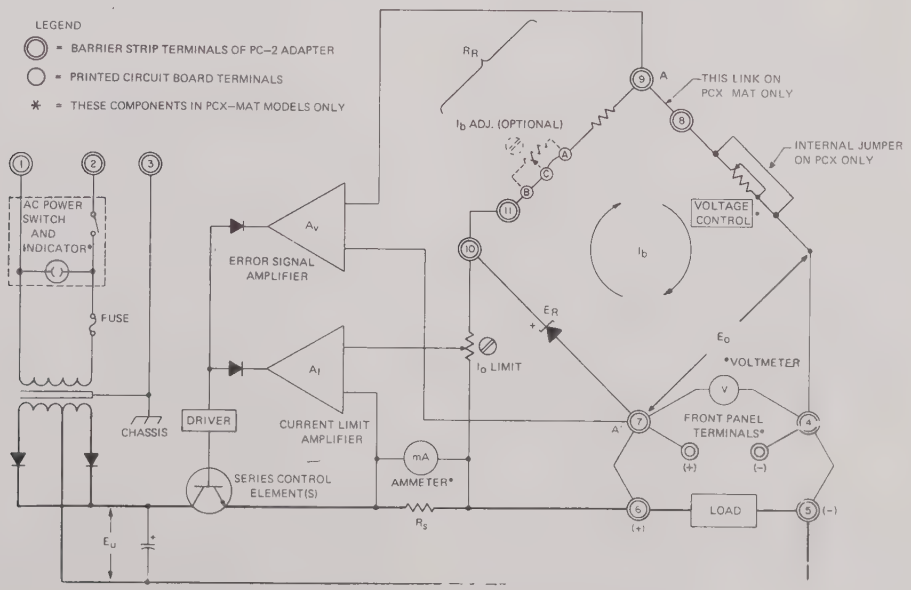


FIG. 4-1 PCX AND PCX–MAT POWER SUPPLY MODULE FEEDBACK REGULATOR SYSTEM (SIMPLIFIED SCHEMATIC)

e) The COMPARISON BRIDGE: This four-arm electrical bridge circuit is the regulating and controlling element in many KEPCO Power Supplies. In the PCX and PCX–MAT Model it consists of CR18 (E_r), R26 (R_r), the output voltage (E_o), and the voltage control resistance (R_{VC}). As shown in FIG. 4-1, a reference voltage (E_r) in series with the reference resistance (R_r) is continuously compared with the output voltage, (E_o) in series with the voltage control resistance, R_{VC}. At balance, a constant bridge current (I_b) is flowing through the bridge, keeping the error signal at bridge terminals (A) and (A') at approximately zero volts. Any deviation from the set output voltage will tend to change I_b in the sensing half of the bridge and thereby produce an error signal at the bridge terminals (A) and (A'). This error signal is then amplified and acts as a control signal for the series regulator transistor, changing the voltage drop across it in such a way as to compensate for the change in output voltage.

f) CURRENT LIMIT CIRCUITRY. The current limiting circuitry has the function to prevent output current flow beyond the maximum rated value. It performs this function by "cutting off" the pass transistor as soon as this value is reached. The differential inputs of the current limit amplifier (A_I = Q3,4) are connected to a current sensing resistor R_S (R16) and to a reference voltage. The voltage drop across R_S (due to load current flow) is continuously compared to the pre-set voltage at the "I_O Limit" control (R19). As long as the voltage developed across R_S is less than the pre-set voltage level at R19, the current amplifier will be biased to its inactive state and will have no effect on the output. Both, the current limit amplifier and error signal amplifier (A_V) are coupled through their respective gate diodes (CR16,17) to the driver transistor (Q2). The amplifier with the larger (negative) output will control the pass elements while the other amplifier is de-coupled. Since the voltage drop across the sensing resistor (R16) is proportional to the output current, and the "I_O Limit" may be set to a voltage exactly equal to that across R_S the current amplifier is inactive as long as the output current does not exceed the pre-set level. If the output current does increase however, the current amplifier will produce an output signal more negative than A_V, thereby taking control away from the voltage amplifier A_V and limiting the output current sharply in the process.

g) AUXILIARY SUPPLIES

1) AMPLIFIER POWER SUPPLY. This full wave, capacitor filtered source consists of a center-tapped winding on T201, silicon rectifier CR1, CR2 and the filter capacitor C1. A current regulator stage (Q1) followed by a string of zener diodes (CR11,CR12,CR13,CR14) provides the operating voltages for the amplifiers and is the source of the temperature compensated reference voltage (CR18). The positive reference voltage serves as the comparison source for the error signal amplifier (A_V) and produces the bridge current. The DC offset control (E_{IO} Null) is also derived from the reference voltage. The offset control allows for precision zeroing of the initial amplifier offset and makes output voltage control to "true zero" possible (R24, on Models with suffix "E" only).

2) DRIVER COLLECTOR SUPPLY: A half-wave, capacitor filtered supply is derived from a winding on T201, rectified by silicon diode CR5 and filtered by C2. It delivers collector voltage to the driver transistor (Q2). R3 is a bleeder and CR15 is the coupling diode to the pass transistor.

3) I_{cbo} SUPPLY: The operating voltage for the I_{cbo} circuitry are derived from the main power supply. Q5 is biased by the voltage drop across the series diodes (CR9,10) in such a way as to draw a relatively constant current, thus providing a current sink for the I_{cbo} of the pass elements. This ensures positive cut-off, especially at high operating temperatures.

5-1 GENERAL

5-2 This section contains instructions for the maintenance, installation of operational controls, internal adjustments (as far as not covered in previous sections) and the performance of test measurements on the PCX and PCX–MAT Power Supplies. Conservative rating of all components and non-congested lay-out should keep maintenance problems to a minimum. If trouble does develop however, the easily removable plug-in board feature of the main component board provides exceptional accessibility to all components of the instrument.

5-3 DISASSEMBLY. (Refer to FIG. 5-1)

5-4 The main component board (PCB #1–A1) may be disassembled for servicing by loosening and removing its four (4) mounting screws and disconnecting the mating plugs.

ATTENTION: When re-assembling the printed circuit board to the main chassis, the distance from the rear of the front panel to the extreme outer edge of the main component board must be 15 inches ±1/32, to insure proper fit into the case or rack-adaptor.

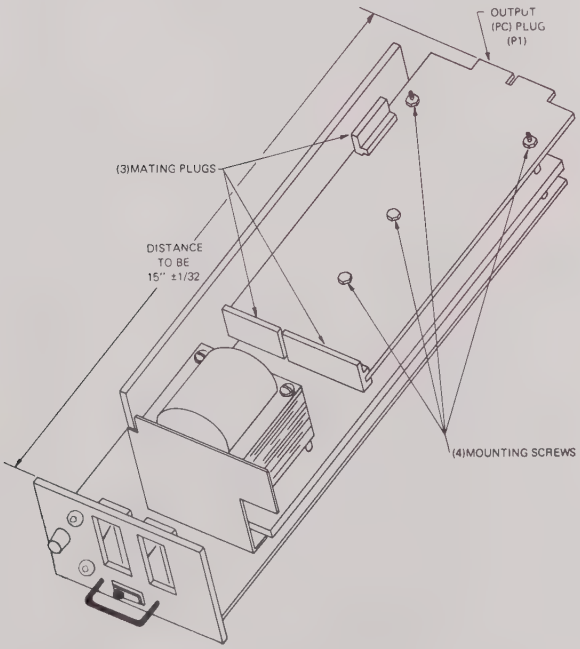


FIG. 5-1 DISASSEMBLY, PCX–MAT

5-5 INSTALLATION AND ADJUSTMENT OF OPTIONAL CONTROL COMPONENTS

5-6 On PCX and PCX–MAT power supplies, pre-designated spaces on the printed circuit board have been provided for the installation of the following optional control rheostats:

a) Bridge current Adjustment ("I_b Adj." R27)
b) Zero Adjustment ("E_{io} null" R24)
c) Voltage Control Adjustment ("R_{VC}" R25). This control is needed on PCX models only, since PCX–MAT Models have a front panel voltage control.

5-7 Models ordered with these controls factory installed bear the suffixes "R" (for R27), "E" (for R24), or a four place suffix "8000" (for R25). The installation instructions may be disregarded for these models. DISCONNECT POWER SUPPLY FROM THE AC INPUT POWER SOURCE. Before installation, remove the printed circuit board as described in paragraph 5-3. Locate predesignated spaces for the controls by referring to FIG. 5-2. Proceed as directed in the applicable paragraphs below.

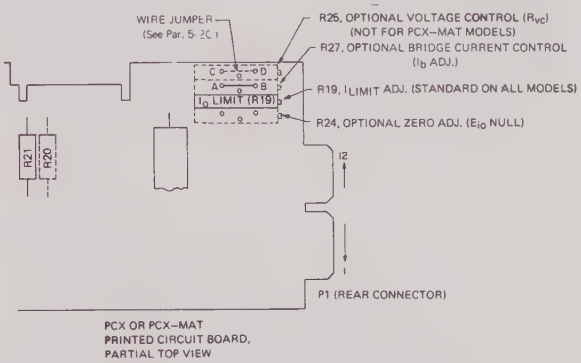


FIG. 5-2 LOCATION OF MOUNTING SPACES FOR OPTIONAL CONTROLS

5-8 Installation and Calibration of Bridge Current Adjustment (R27).

a) Remove jumper between terminals marked "A" and "B."
b) Insert 1 K ohm in the space outlined on FIG. 5-2. Solder in place and turn R27 to its approximate midposition. Reinstall the circuit board, and return power supply to the plug-in adaptor.
c) Install a precision resistor (R_{VC}) across barrier-strip terminals (4) and (9) and connect a precision voltmeter across the output terminals (5) and (6).* Since the bridge current (I_b) is a nominal 1 mA, and the control ratio is 1 K ohm/V, the output voltage E_O will be approximately equal to $E_O = I_b R_{VC}$. (i.e., for each 1000 ohms of voltage control resistance [R_{VC}], one volt of output voltage will appear across the output terminals.)

*On PCX–MAT Models, disconnect the internal voltage control by removing the jumpers between rear barrier strip terminals (8) and (9).

d) Connect power supply to the AC input power source, turn unit "on" and read the output voltage. Adjust R27 until E_O is exactly equal to the number of kilohms of R_{VC}. The accuracy of the adjustment is limited only by the tolerances of R_{VC} and by the accuracy of the voltmeter across the output terminals.

5-9 INSTALLATION AND CALIBRATION OF THE ZERO ADJUSTMENT (R24)

a) Remove R21 (499 K ohm) from the printed circuit board and install R20 (10 ohm) in the space indicated.

b) Insert 50 K rheostat (R24) into the indicated space and solder in place. Turn R24 to its approximate mid positon.

c) Connect a short wire between rear barrier strip terminals (4) and (9), and connect a precision null reading meter across the output terminals (5)-(6). Since the voltage control (R_{VC}) is now zero (shorted out), the output voltage should be equal to

$$E_O = I_b\ (0) = 0 \text{ Volts}$$

d) Connect power supply to AC power line and turn unit on. The small (negative) voltage at the output is the offset voltage of the power supply amplifier. Set to exact zero by adjusting R24, increasing the sensitivity of the null meter until the desired zero accuracy is achieved.

5-10 INSTALLATION OF THE OUTPUT VOLTAGE ADJUSTMENT (R_{VC}—R25)

a) On PCX Models, which are not equipped with a front panel voltage control, the control resistor may be connected externally as described previously (See Section III, Par. 3-23) In addition, a space is provdied on the printed circuit board, which accepts a trim rheostat for output voltage control.

b) Locate appropriate space on the printed circuit board (refer to FIG. 5-2), remove the wire jumper, and solder the selected rheostat in place. The value of the rheostat will depend on the desired output voltage, i.e., for each 1000 ohms of resistance, 1 volt of output will be produced.

c) Instead of a rheostat, a fixed resistor may be soldered in place for such applications where only a fixed output voltage is required. Precision calibration of the output voltage in the latter case may be performed with the "I_b Adjust" (R27) control.

5-11 CURRENT LIMIT ADJUSTMENT

5-12 The "I_O Limit" adjustment (R19) is factory set to limit the output current at approximately 105% of the maximum rated value of the particular model. Re-adjustment is indicated if either components in the current limiting circuit have been replaced or, if a limiting value lower than the factory-set value is desired. The adjustment can be performed conveniently by following the steps outlined below:

a) Connect an ammeter in series with the load (on metered PCX—MAT Models the panel meter may be used) and adjust load to draw the desired output current plus 10% I_O max. rated. Monitor the output across the load with an oscilloscope (vertical sensitivity 0.1 mV/cm).

b) Locate R19 (Refer to FIG. 5-2) Slowly turn the control counter clockwise until a sharp increase in output ripple is observed, indicating the operation of the power supply in the current limit mode. Set control slightly clockwise again until the output ripple appears just normal again.

c) Short circuit the load and observe the short circuit current on the ammeter. Re-adjust if necessary. DO NOT SET THE "I_O Limit" ADJUSTMENT HIGHER THAN 105% of I_O max. rated. Although this may be possible due to component tolerances, excessive dissipation across the pass-elements will result and destroy these transistors if the current limit is set too high.

5-13 TROUBLE SHOOTING

5-14 The repair of modern, electrically complex voltage/current sources or operational devices, requires a thorough understanding of closed loop feedback systems and experience with solid state circuitry. The nature of a feedback system renders the so called "Trouble Shooting Charts", containing resistance, voltage/current readings and/or various fault conditions, almost useless. A more sophisticated approach is essential. To assist the user in such an approach when a mal-function occurs, this manual contains:

a) An extensive operational theory (Section III)

b) A circuit description with simplified diagram. (Section IV).

c) Detailed diagrams showing internal controls and parts location. (Section V)

d) The main schematic, containing the complete circuitry, all plug-in inter-connections and all significant voltage readings under specified conditions.

5-15 It has been found in out experience, that in many cases of malfunction, the trouble can be traced to external causes. It is suggested therefore, if a case of "power supply failure" is encountered, to disconnect all external programming or input sources and operate the instrument locally, as directed in Section III. If the power supply does not perform in the standard operating mode, the following basic steps may be found useful:

a) NO OUTPUT. Check AC input source for correct line voltage. Refer to Section II of this manual if the transformer connections are correct for the prevailing AC input voltage. (Instrument is normally delivered for 115 V AC operation.) Check fuse and replace if it is open. For case or rack-mounted units: check proper alignment of the printed circuit board connector with its mating plug, and realign if necessary. (Distance from behind panel to end of PCB plug = 15 inch ± 1/32.)

b) HIGH OUTPUT. Unregulated output is accompanied by excessive output "ripple," and the output voltage or current cannot be controlled by the standard panel or rear controls. Check rear terminal connections. Secure all jumper-links as well as load leads connected to the supply. Proceed to circuit analysis. Unregulated output indicates an open feedback loop. Check reference voltage, current and/or voltage control resistors, transistors and amplifier. Inpsect printed circuit board for visual damage of components.

c) POOR PERFORMANCE. If the instrument is basically functioning, but poor performance is evident inspect the test set-up and follow the performance measurements, outlined in paragraph 5-16. Poor DC performance is often due to incorrectly connected instrumentation or other faulty measurement techniques. Follow the recommended procedures and refer to the applicable diagrams. High-frequency oscillation as observed at the output or across the load is often due to loads with an excessive reactive component. An additional capacitor (0.1 to 0.5 μF) may be connected across rear terminals (4)-(9), or additional capacitive decoupling directly at the load may produce results.

5-16 PERFORMANCE MEASUREMENTS

5-17 GENERAL. Valid evaluation of the specified power supply parameters requires a controlled environment and specialized test equipment. Since however, acceptance testing or performance checks are a frequent requirement for incomming inspection, periodic maintenance, or after component replacement, suggestions for the performance of some significant measurements are given in the following paragraphs. It must be emphasized that the given procedures are to be followed closely if valid results are expected.

5-18 DC OUTPUT EFFECT MEASUREMENTS (VOLTAGE MODE)

a) REQUIRED INSTRUMENTATION:
   1) AC INPUT SOURCE with provisions for "stepping" the voltage over the specified region (105–115 V AC or 210–250 V AC), a variable autotransformer is adequate if it is rated to deliver the required AC input current of the unit under test.
   2) RESISTOR LOAD, variable, with "on-off" switch and rated to dissipate the full output power of the unit under test.
   3) DC PRECISION VOLTMETER, differential type, with a resolution of 1 mV or better, for line/load regulation measurements (M1).
   4) AC VOLTMETER, "true rms" reading type, with a sensitivity of at least 1 mV full scale (M2).
   5) OSCILLOSCOPE, vertical sensitivity better than 0.1 mV/cm.

b) The importance of proper application of the four-terminal network technique in measuring output effects including ripple cannot be overemphasized. The principle governing this method of measurement is simply: DO NOT MEASURE ANY VOLTAGE DROPS DUE TO LOAD CURRENT FLOW since these errors would be included in the actual parameters which we are trying to determine and would thus falsify the results. (Refer to FIG. 5-5.)

c) MEASUREMENT OF OUTPUT EFFECT DUE TO AC INPUT SOURCE VARIATIONS. Set up test circuit as shown in FIG. 5-3. Measure output effect by varying the AC input source between the specified limits and noting the deviation (ΔE_O) on the meter across the output. The output effect due to AC input source variations is specified in percent of the maximum rated output voltage.

$$\% \text{ Output Effect} = \frac{\Delta E_O}{E_O} \times 100\%, \text{ where}$$

E_O is the output voltage of the unit under test and ΔE_O is equal to the change across M1 as the AC source voltage is varied between the specified limits

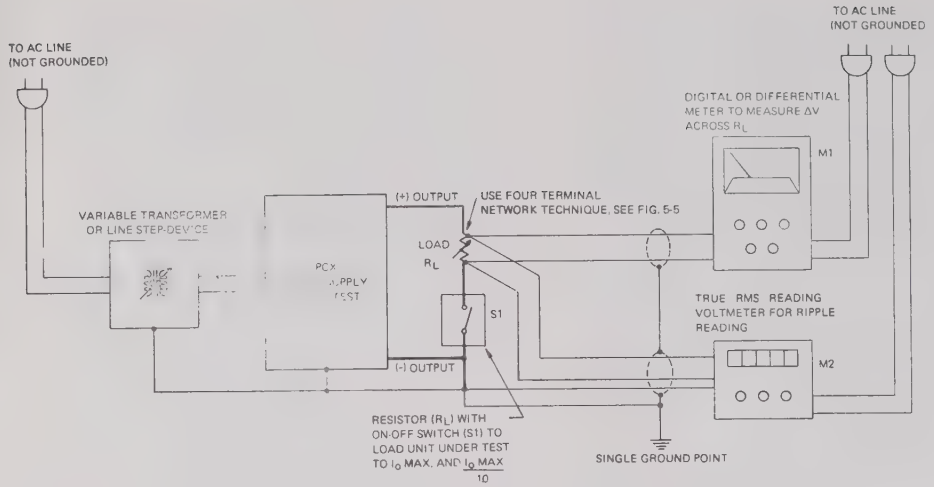


FIG. 5-3 TEST SETUP FOR VOLTAGE REGULATION MEASUREMENTS.

d) MEASUREMENT OF OUTPUT EFFECT DUE TO LOAD VARIATIONS. Retain the test setup shown in FIG. 5-3. Set the AC input source to 115V AC. Measure output effect by opening and closing the load switch (S1) and noting the deviation ΔE_O on M1. The output effect due to load variations is specified in percent of the maximum rated output voltage:

$$\% \text{ Output Effect} = \frac{\Delta E_O}{E_O} \times 100\%$$

e) RIPPLE MEASUREMENT. Ripple is specified in absolute values (rms). Careful wire-dressing and shielding, as well as good AC grounding are of the utmost importance to get valid results. (Use single ground point as shown in FIG. 5-3.)

5-19 DC OUTPUT EFFECT MEASUREMENTS (CURRENT MODE)

a) REQUIRED INSTRUMENTATION:

1) AC INPUT SOURCE with provisions for "stepping" the voltage over the specified region (105–115 V AC or 210–250 V AC), a variable autotransformer is adequate if it is rated to deliver the required AC input current of the unit under test.

2) RESISTOR LOAD, variable, with shorting switch and rated to dissipate the full output power of the unit under test (R_L).

3) DC PRECISION VOLTMETER, differential type, with a resolution of 1 mV or better, for line/load regulation measurements (M1).

4) AC VOLTMETER, "true rms" reading type, with a sensitivity of at least 1 mV full scale (M2).

5) OSCILLOSCOPE, vertical sensitivity better than 0.1 mV/cm.

6) CURRENT MEASURING RESISTOR, four-terminal type, rated to drop one volt at the maximum output current, and one piece rated to drop one volt at 10% of the rated maximum output current. Wattage at least 10 times the actual dissipated power.

b) The importance of proper application of the four-terminal network technique in measuring output effects cannot be overemphasized. The principle governing this method of measurement is simply: DO NOT MEASURE ANY VOLTAGE DROPS DUE TO LOAD CURRENT FLOW since these errors would be included in the actual parameters which we are trying to determine and would thus falsify the results. (Refer to FIG. 5-5.)

c) MEASUREMENT OF OUTPUT EFFECTS DUE TO AC INPUT SOURCE VARIATIONS. Set up test setup as shown in FIG. 5-4. Measure output effect by varying the AC line between the specified limits and noting the deviation (ΔV) on the meter across R_m. The output effect due to AC input source variations is specified in percent of the maximum rated output current.

$$\% \text{ Output Effect} = \frac{\Delta I_O}{I_O} \times 100\%, \text{ where}$$

I_O is the output current of the unit under test and ΔI_O is equal to: $\Delta I_O = \frac{\Delta V}{R_m}$ where

V is the sample across the measuring resistor (R_m) and ΔV is the change measured by the meter.

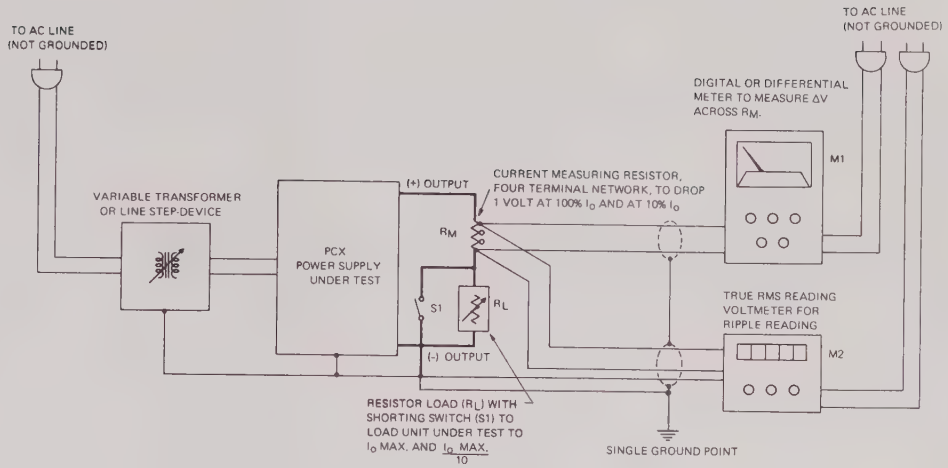


FIG. 5-4 TEST SET-UP FOR CURRENT REGULATION MEASUREMENTS

d) MEASUREMENT OF OUTPUT EFFECT DUE TO LOAD VARIATIONS. Retain the test setup shown in FIG. 5-4. Set the AC input source to 115 V AC. Measure output effect by opening and closing the load switch (S1) and noting the deviation (ΔV) on the meter across R_m. The output effect due to load variations is specified in percent of the maximum rated output current (and in μA):

$$\% \text{ Output Effect} = \frac{\Delta I_o}{I_o} \times 100\%, \text{ where}$$

I_o is the output current of the unit under test and ΔI_o is equal to: $\Delta I_o = \frac{\Delta V}{R_m}$ where

V is the sample across the measuring resistor (R_m) and ΔV is the change measured by the meter.

e) RIPPLE MEASUREMENT. Ripple is specified in percentage of the maximum rated output current. To convert the reading across the measuring resistor (mV) to the proper units (mA), the reading must be divided by the value of the measuring resistor:

$$\text{Ripple} = \frac{V_s}{R_m} \text{ (mA rms)}$$

Careful wire dressing and shielding, as well as good signal grounding, are of the utmost importance to get valid results. (Use single ground point as shown in FIG. 5-4.)

5-20 INTERCHANGE OF PCX/PCX–MAT AND PBX/PBX–MAT MODULES

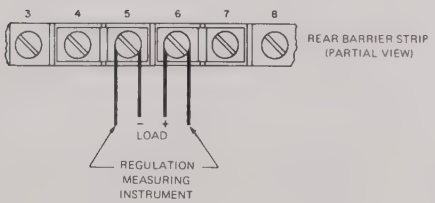
5-21 Kepco's PCX/PCX–MAT and former PBX/PBX–MAT modules are directly interchangeable (on a model for model basis) so that no alternations on existing installations using the PBX/PBX–MAT groups are required. For a PCX–PBX interchange no modifications on the PCX are needed. When replacing a PBX–MAT with its PCX–MAT counterpart, a modification is required only if the latter is used in one of the remote programming modes. In this case, an internal jumper must be placed on a prepared space on the circuit board to make the rear terminations of the PCX–MAT match with that of the PBX–MAT.

5-22 PROCEDURE

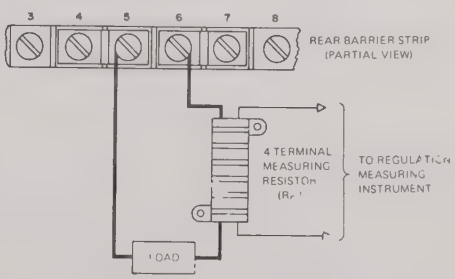
a) Locate prepared space on PCB-1 (A1) by referring to FIG. 5-22.

b) Place wire jumper between points "C" and "D" and solder in place.

c) The rear terminal configuration matches now exactly with that of the PBX–MAT series.



a) VOLTAGE MODE MEASUREMENTS



b) CURRENT MODE MEASUREMENTS

FIG. 5-5 APPLICATION OF THE 4 TERMINAL–NETWORK TECHNIQUE FOR POWER SUPPLY MEASUREMENTS.

SECTION VI—ELECTRICAL PARTS LIST AND DIAGRAMS

6-1 GENERAL

6-2 This section contains the main schematic, the parts location diagrams, and a list of all replaceable electrical parts. All components are listed in alpha-numerical order of their reference designations. Consult your Kepco Representative for replacement of parts not listed here.

6-3 ORDERING INFORMATION

6-4 To order a replacement part or to inquire about parts not listed in the parts list, address order or inquiry either to your authorized Kepco Sales Representative or to:

KEPCO, INC.
131-38 Sanford Avenue
Flushing, N.Y. 11352

6-5 Specify the following information for each part:

a) Model and complete serial number of instrument.
b) Kepco part number.
c) Circuit reference designator.
d) Description.

6-6 To order a part not listed in the parts list, give a complete description and include its function and location.

NOTE: KEPCO DOES NOT STOCK OR SELL COMPLETE POWER SUPPLY SUBASSEMBLIES AS DESCRIBED HERE AND ELSEWHERE IN THIS INSTRUCTION MANUAL. SOME OF THE REASONS ARE LISTED BELOW:

1) Replacement of a complete subassembly is a comparatively rare necessity.
2) Kepco's subassemblies are readily serviceable, since most of them are of the "plug-in" type.
3) All active componets are socket mounted, making replacement extremely easy.
4) The nature of a closed-loop power supply system requires that subassembly replacement is followed by careful measurement of the total power supply performance. In addition, depending on the function of the subassembly, extensive alignment may be required to restore power supply performance to specified values.

IF REPAIRS INVOLVING SUBASSEMBLY REPLACEMENTS ARE REQUIRED, PLEASE CONSULT YOUR LOCAL KEPCO REPRESENTATIVE OR THE KEPCO SALES ENGINEERING DEPARTMENT IN FLUSHING, NEW YORK, N.Y.

ABBREVIATIONS USED IN KEPCO PARTS LISTS

A) Reference Designators:

A	= Assembly
B	= Blower (Fan)
C	= Capacitor
CB	= Circuit Breaker
CR	= Diode
DS	= Device, Signaling (Lamp)
F	= Fuse
FX	= Fuse Holder
IC	= Integrated Circuit
J	= Jack
K	= Relay
L	= Inductor
LC	= Light-Coupled Device
M	= Meter
P	= Plug
Q	= Transistor
R	= Resistor
S	= Switch
T	= Transformer
TB	= Terminal Block
V	= Vacuum Tube
X	= Socket

B) Descriptive Abbreviations

A	= Ampere
a-c	= Alternating Current
AMP	= Amplifier
AX	= Axial
CAP	= Capacitor
CER	= Ceramic
CT	= Center-Tap
°C	= Degree Centigrade
d-c	= Direct Current
DPDT	= Double Pole, Double Throw
DPST	= Double Pole, Single Throw
ELECT	= Electrolytic
F	= Farad
FILM	= Polyester Film
FLAM	= Flammable
FP	= Flame-Proof
°F	= Degree Fahrenheit
FXD	= Fixed
Ge	= Germanium
H	= Henry
Hz	= Hertz
IC	= Integrated Circuit
K	= Kilo (10^3)
m	= Milli (10^{-3})
M	= Mega (10^6)
MFR	= Manufacturer
MET	= Metal
n	= Nano (10^{-9})
NC	= Normally Closed
NO	= Normally Open
p	= Pico (10^{-12})
PC	= Printed Circuit
POT	= Potentiometer
PIV	= Peak Inverse Voltage
p-p	= Peak to Peak
ppm	= Parts Per Million
PWR	= Power
RAD	= Radial
RECT	= Rectifier
RECY	= Recovery
REG	= Regulated
RES	= Resistor
RMS	= Root Mean Square
Si	= Silicon
S-End	= Single Ended
SPDT	= Single Pole, Double Throw
SPST	= Single Pole, Single Throw
Stud Mt	= Stud Mounted
TAN	= Tantalum
TSTR	= Transistor
μ	= Micro (μ) (10^{-6})
V	= Volt
W	= Watt
WW	= Wire Wound

PRINTED CIRCUIT BOARD (A1), MODEL PCX 15–1.5MAT (R)(T)(E) Code 10-2869

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (SEE NOTE)	KEPCO PART NO.
Av	1	Plug-In Amplifier	Kepco 250-0013	250-0013
C1	1	Capacitor,Electrolytic,Pigtail 75 μF, 50 V	Sprague 30D756G050DF2	117-0646
C2	1	Capacitor,Electrolytic,Pigtail 290 μF, 12 V	Sprague 30D297G012DF2	117-0647
C3A&B	2	Capacitor,Electrolytic,Pigtail 825 μF, 40 V	General Electric 43F7580AA1	117-0430
C4	1	Capacitor,Ceramic,Disc. 5,000 pF, 500 V, 20%	Radio Materials Type SM	117-0061
C5	1	Capacitor,Mylar,Pigtail 0.1 μF, 600 V, 20%	TRW X663F	117-0316
C6,8	2	Capacitor,Electrolytic,Pigtail 150 μF, 3 V, 20%	General Electric 76F02BF151	117-0512
C7	1	Capacitor,Electrolytic,Pigtail 500 μF, 30 V	Sprague 38D507G030FL2	117-0621
C9	1	Capacitor,Mylar,Pigtail 0.2 μF, 200 V, 10%	TRW X663F	117-0236
CR1,2,3, 15,16,17	6	Rectifier,Silicon,Pigtail	Semteck Corp. SE1	124-0133
CR4,5,6, 7,9,10,20	7	Rectifier,Silicon,Pigtail	Semicon S5A1	124-0347
CR8,11,12, 13,14	5	Zener Diode	Transitron 1N763-1	121-0028
CR18	1	Zener Diode	International Resistance 1N821	121-0041
	1	Zener Diode	IRC 1N827	121-0062*
CR19,21	2	Rectifier,Silicon,Pigtail	Solitron 124-0178	124-0178
F1	1	Fuse,Slow Blow 0.8 A	Bussman MDL 8/10	141-0027
Q1,2,3,4,5	5	Transistor,Silicon,NPN	M.S. Transistor 119-0056	119-0056
R1	1	Resistor,Fixed,Precision,M.F. 232 ohm, 1/4 W, 1%	IRC CEA Type	115-2310
R2	1	Resistor,Fixed,M.G. 82 K ohm, 1/4 W, 5%	IRC RG 1/4	115-2012
R3	1	Resistor,Fixed,Molded 3.9 K ohm, 1/2 W, 5%	Allen Bradley EB3925	115-0808
R4	1	Resistor,Fixed,Molded 1 K ohm, 1/2 W, 10%	Allen Bradley EB1011	115-0547

*For PCX15–1.5MATT only.

NOTE:
REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

PRINTED CIRCUIT BOARD (A1), MODEL PCX 15–1.5MAT (R)(T)(E) Code 4-169

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (SEE NOTE)	KEPCO PART NO.
R5	1	Resistor,Fixed,Molded 560 ohm, 1/2 W, 10%	Allen Bradley EB5611	115-0451
R6	1	Resistor,Fixed,M.G. 39 ohm, 1/4 W, 5%	IRC RG 1/4	115-2307
R7,11	2	Resistor,Fixed,Power,Axial 750 ohm, 3 W, 5%	Hardwick Hindle 9/16 GA-46-750	115-0885
R8	1	Resistor,Fixed,Power,Axial 1.5 K ohm, 3 W, 5%	Tepro TS-3C	115-1189
R9,29	2	Resistor,Fixed,Power,Axial 0.5 ohm, 3 W, 5%	Hardwick Hindle 9/16 GA-46-0.5	115-0504
R10	1	Resistor,Fixed,Molded 120 ohm, 1/4 W, 10%	IRC GBT 1/4	115-2232
R12	1	Resistor,Fixed,Molded 47 K ohm, 1/4 W, 10%	IRC GBT 1/4	115-2237
R13	1	Resistor,Fixed,M.G. 6.2 K ohm, 1/4 W, 5%	IRC GBT 1/4	115-2258
R15	1	Resistor,Fixed,Molded 1.5 K ohm, 1/4 W, 10%	IRC GBT 1/4	115-2229
R16	1	Resistor,Fixed,Precision,WW 0.333 ohm, 2 1/2 W, 1%	Tepro TS-2C	115-1107
R17	1	Resistor,Fixed,Molded 10 ohm, 1/4 W, 10%	IRC GBT 1/4	115-2230
R18	1	Resistor,Fixed,Molded 10 K ohm, 1/4 W, 10%	IRC GBT 1/4	115-2211
R19	1	Resistor,Variable,Cermet 2 K ohm, 3/4 W, 20%	Helipot 78PR2K	115-2032
*R20	1	Resistor,Fixed 10 ohm, 1/2 W, 10%	Allen Bradley EB 1001	115-0502
R21	1	Resistor,Fixed,Precision,M.F. 499 K ohm, 1 W, 1%	IRC CES Type	115-1956
R22	1	Resistor,Fixed,Precision,M.F. 10 K ohm, 1/4 W, 1%	IRC CEA Type	115-2174
R23	1	Resistor,Fixed,Precision,M.F. 750 ohm, 1/4 W, 1%	IRC CEA Type	115-2259
*R24	1	Resistor,Variable,Cermet 50 K ohm, 3/4 W, 20%	Beckman 78PR50K	115-2104
R26	1	Resistor,Fixed,Precision,WW 5.7 K ohm, 1 W, 1%	Tepro TS-1W	115-1301
**R27	1	Resistor,Variable,Cermet 1 K ohm, 3/4 W, 20%	Helipot 78PR1KW	115-2035

*For PCX 15–1.5MAT (E) only (R21 deleted)
**For PCX 15–1.5MAT (R) only.

NOTE:
REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

MAIN CHASSIS (A2), MODEL PCX 15–1.5MAT (R)(T)(E)

Code 2-669

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (SEE NOTE)	KEPCO PART NO.
FRONT PANEL ASSEMBLY CONTAINS:				
M101	1	Meter,Volt 0–15V	Honeywell Model 504	135-0410
M102	1	Meter,Amp. 0–1.5A	Honeywell Model 504	135-0426
R101	1	Resistor,Variable,WW 15 K ohm, 1.5 W, 5%	IRC Type 5000	115-2167
Q201,202	2	Transistor,Silicon,NPN	Solitron 119-0082	119-0082
SDS201	1	Switch & Pilot Light	Lee Craft 127-0229	127-0229
T201	1	Transformer	Kepco Magnetics 100-1768	100-1768

MISCELLANEOUS COMPONENTS, MODEL PCX 15–1.5MAT (R)(T)(E)

	1	Front Panel Handle	H.H. Smith 1637	139-0212
	1	Front Panel Voltage Control Knob	Buckeye Stamping SSN-50-2	155-0048
	1	Front Panel Output Jack (Red)	Raytheon 276-1569G4	173-0001
	1	Front Panel Output Jack (Black)	Raytheon 276-1569G6	173-0002

NOTE:

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

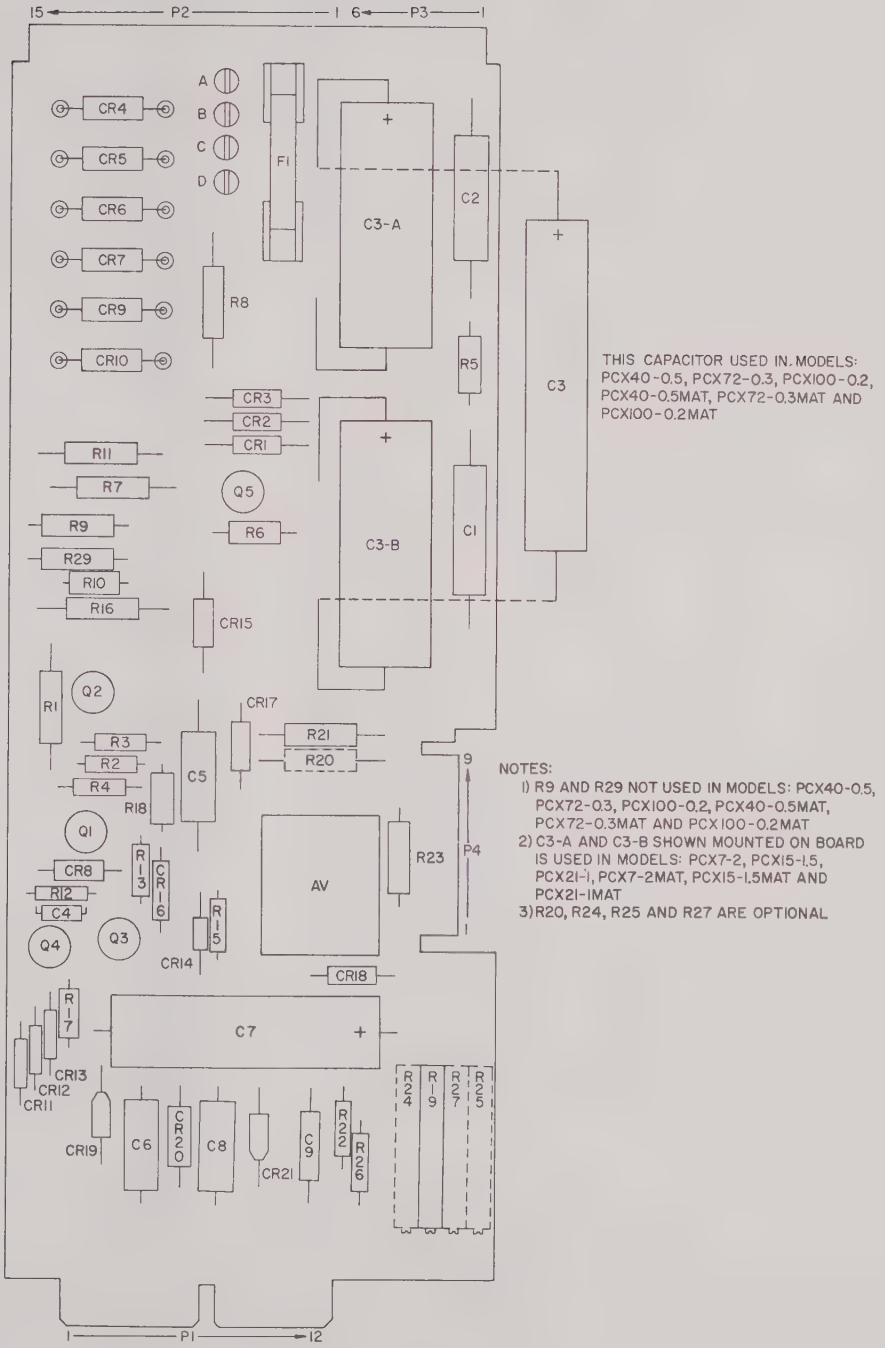


FIG. 6-1 COMPONENT LOCATION, PCB

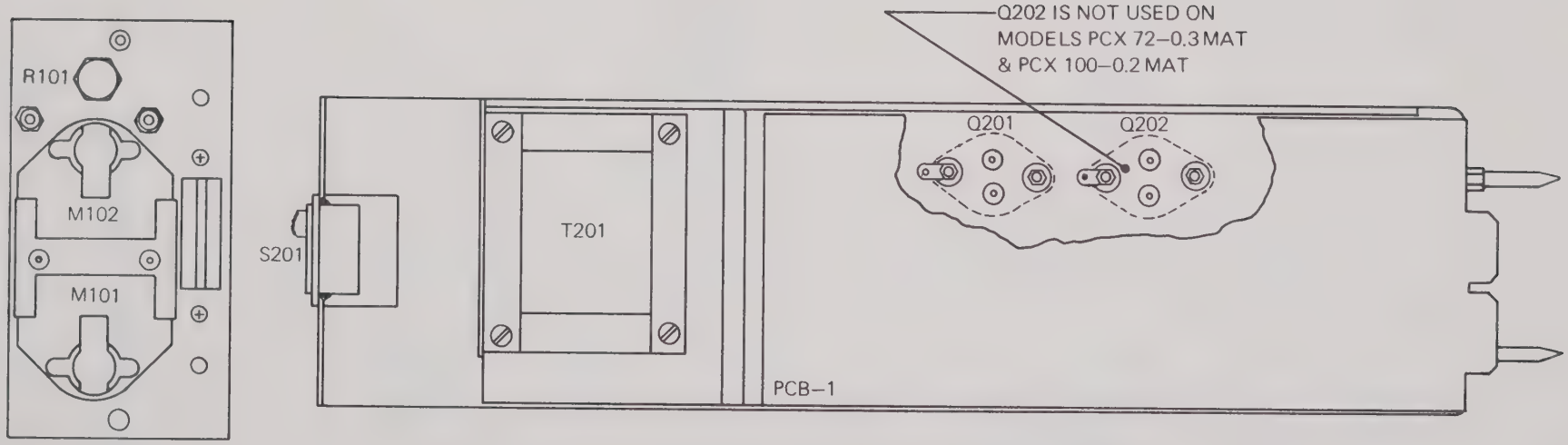
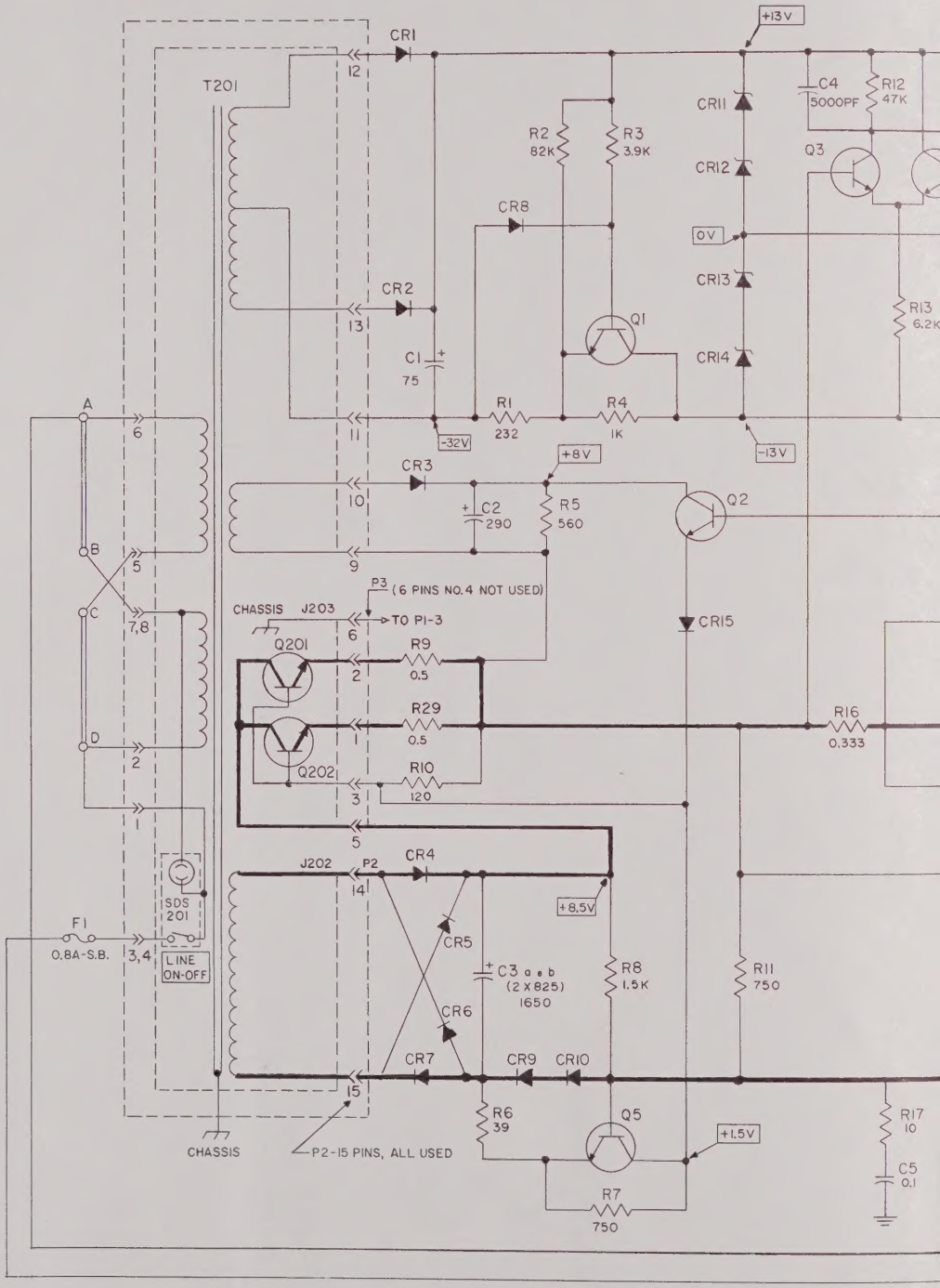


FIG. 6-2 COMPONENT LOCATION, MAIN CHASSIS



NOTES:

1. RESISTOR VALUES IN OHMS, K=1000.
2. CAPACITOR VALUES IN MICROFARADS, UNLESS INDICATED OTHERW
3. PINS (4)-(5), (6)-(8), (9)-(10) AND (11)-(12) ON P1 MUST BE S
   FOR STANDARD OPERATION.
4. CONDITIONS FOR LISTED VOLTAGE READINGS.
   A) LINE AT 115 VAC, 60 Hz.
   B) METER: 20K OHMS PER VOLT.
   C) REFERENCE POINT: COMMON (+SENSE).
   D) MAXIMUM OUTPUT VOLTAGE, NO LOAD.
   E) READINGS SUBJECT TO NORMAL COMPONENT TOLERANCES.
5. MAIN TRANSFORMER CONNECTIONS SHOWN FOR 115 VAC OPER

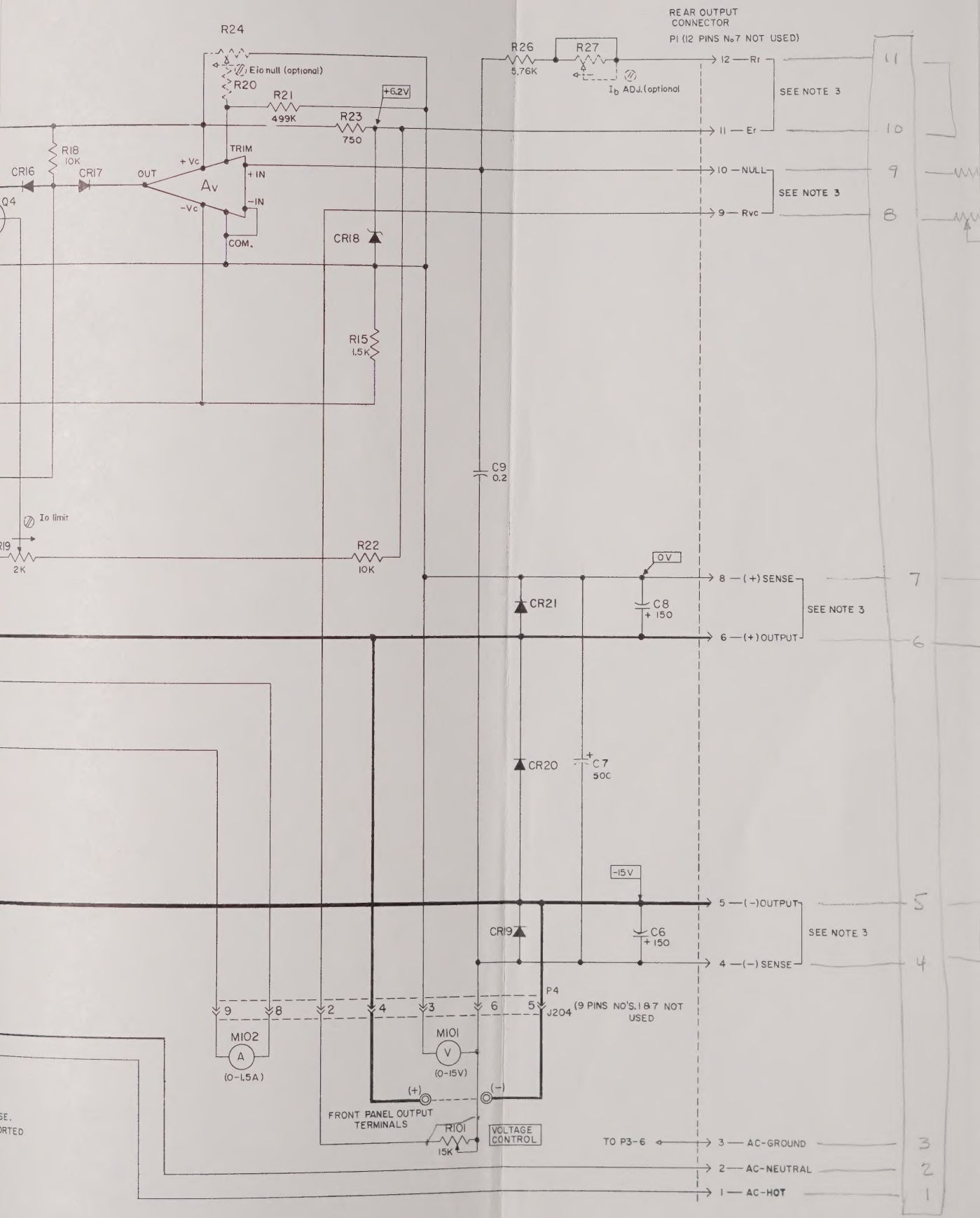
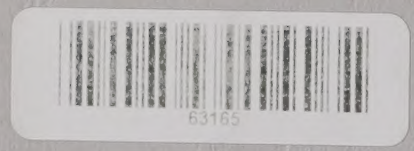


FIG. 6-3 MAIN SCHEMATIC, MODEL PCX 15–1.5 MAT



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